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THE NEW METHOD OF "GRAPHICAL STATICS."

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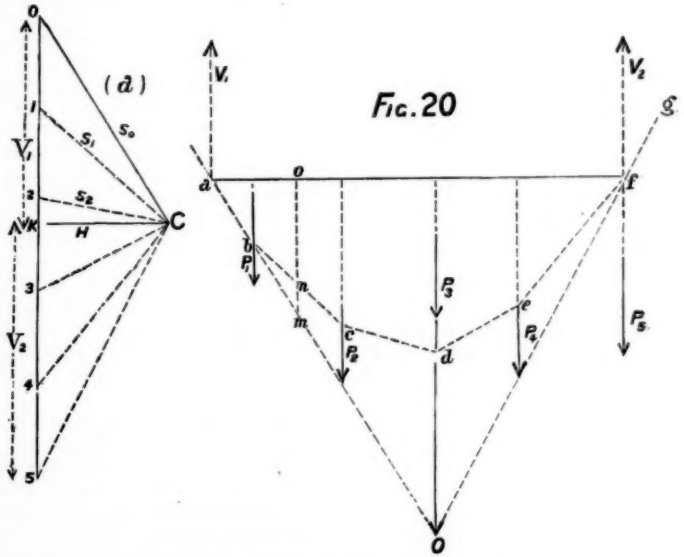
38. EQUILIBRIUM POLYGON.

Since the forces acting upon structures are generally due to the action of gravity, these forces may be considered as parallel and vertical, and in all practical cases therefore we have to do with a system of parallel forces.



Given any number of parallel forces $P_{1\text{-}5}$ Fig. 20; required to find the direction, intensity and position of the resultant, and the moment of rotation at any point.

1st. Draw the *force polygon* (*a*). In this case it is of course a straight line.

2d. Choose a *pole* C, and draw the lines S_0 S'_1 S'_2, etc.

3d. Draw the string or equilibrium polygon *a b c d e f*. Considering this polygon as a system of *strings*, the forces will be held in equilibrium if we join any two points, as *a* and *f*, by a strut or compression piece, and apply at *a* and *f* the upward forces V_1 and V_2.

4th. Prolong *ab* and *fg* to their intersection O. Through this point the resultant must pass. It is of course parallel and equal to the sum of the forces.

Now, if *a f* is assumed horizontal, the perpendicular H to the force line, or the "*pole distance*," divides the resultant 0 5 into the two forces V_1 and V_2.

All the forces in the equilibrium polygon, have the same horizontal projection H, in the force polygon.

Let *a f* represent a *beam* resting upon supports at *a* and *f*. We have then at once the vertical reactions V_1 and V_2 or K 0 and 5 K, which, in order to cause equilibrium, must act *upwards*.

For the moment at any point, as 0, due to V_1, we have, by Calmunn's principle, m 0 multiplied by H. The triangle formed by *ab*, *af*, and P_1, gives then the moment of rupture at any point of the beam as far as P_1. For a point 0, beyond P_1, the moment due to V_1, must be *diminished* by that due to P_1, since these forces act in opposite directions, and rotation from left to right is considered positive. We see at once from the force polygon (*a*) that P_1 is resolved into S_0 and S_1 or into *a b* and *b c*. Hence the moment at 0 due to P_1 is *m n* multiplied by H. The total moment at *o* is then *m o* − *m n* = *n o*, multiplied by H.

Hence we see that *the ordinates to the equilibrium polygon from the closing line a f are proportional to the total moments, while the ordinate at any point between any two adjacent sides of this polygon, prolonged, represents the moment at that point of a force acting in the vertical through the intersection of these two sides.*

[The reader should make the construction, changing the *order* in which the weights are taken, and thus satisfy himself that the order is a matter of indifference. As to the *direction* of the reactions V_1, V_2, it must be remembered that *a b* is to be *replaced* by V_1 and H, hence V_1 must be opposed to C 0, the direction obtained by following round in the force polygon the triangle 0 I C. Force and distance *scales* should also be assumed. Thus the ordinates to the equilibrium polygon scaled off say in inches, and multipled by the number of tons to one inch, and then by the "pole distance" taken to the assumed scale of distance, will give the moments of any point.]

The resultant of *any* two or more forces must pass through the intersection of the outer sides of the equilibrium polygon for those forces (art. 16). Thus, the resultant of P_1 and P_2 must pass through the intersection of *a b* and *c d*. Of V_1 and P_1, through the intersection of *a f* and *b c*; of $P_1 P_2$ and P_3, through intersection of *a b* and *d e*, and so on. In every case the intensity and direction of action of the resultant is given directly by simple inspection of the force polygon.

Thus from the force polygon we see that the resultants K 2 and K 3 of $V_1 P_1$ P_2 and $V_1 P_1 P_2 P_3$, act in *different* directions. Their points of application are at the intersection of *c d* and *d e* respectively with *a f*, or upon either side of *d* in the equilibrium polygon. At *d* the ordinate and hence the moment is greatest, and at this point the tangent to the polygon is parallel to *a f*. If we had a continuous succession of forces; if *a f*, for instance were continuously or uniformly loaded; the equilibrium polygon would become a *curve*, and the tangent at *d* would then coincide with the very short polygon side at that point. The points of application of the resultants of all the forces right and left of *d* are then at the intersection of this tangent with *a f*, or *at an infinite distance.*

At *d* then we have a *couple*, the resultant of which is as we have seen (art. 20), an indefinitely small force acting at an indefinitely great distance. That is, with reference to *d*, the forces acting right and left cannot be replaced by a single force.

Hence generally: at the point of maximum moment ("*cross section of rupture*"), the sum of the outer forces on either side reduces to an indefinitely small and distant force, the direction of which is reversed at this point, and the point of application of which changes from one side to the other of the equilibrium polygon.*

* *Die Graphische Statik.* –*Culmann, p.* 127.

The "*cross section of rupture*," then, *is that point where the sum of the forces between it and one end is equal to the reaction at that end, or where the resultant of these forces changes sign.*

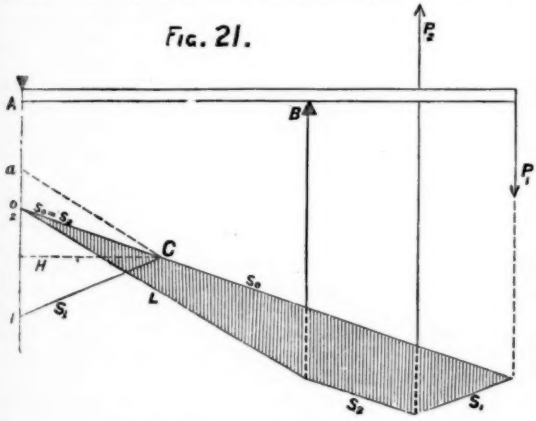
The *value of the moment* at this point, is therefore *equal to the product of the reaction at one end into its distance from the point of application of the resultant of all the forces between that end and the point.*

Thus for a beam uniformly loaded with w per unit of length, the reaction at each end is $\frac{wl}{2}$. From the above, the cross section of rupture is then at the middle. The point of application of the resultant of the forces acting between one end and the middle is at $\frac{l}{4}$, hence the maximum moment is $\frac{wl}{2}\times\frac{l}{4}=\frac{wl^2}{8}$.

39. BEAM WITH TWO EQUAL AND OPPOSITE FORCES BEYOND THE SUPPORTS.

The ordinates to the equilibrium polygon thus give, as it were, a *picture* or simultaneous view of the change and relative amount of the moments at any point. The point where the moment is greatest, *i.e.*, where the beam is most strained, is at once determined by simple inspection.

Fig. 21.



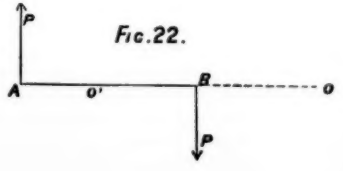
Let us take as an example a beam with two equal and opposite forces *beyond* the supports. Thus, Fig. 21, suppose the beam has supports at A and B, the forces being taken in the order as represented by P_1 P_2. We first construct the force polygon from o to 1, and 1 to 2 or o. Next choose a pole C, and draw S_0 S_1 and S_2. Draw then a parallel to S_0 till intersection with P_1, then parallel with S_1 to P_1, then parallel to S_2 or S_0 to intersection with vertical through support B, and finally draw the *closing line* L. A line through C, parallel to L, gives as before the vertical reactions. Following round the force polygon, we find at A the reaction *downwards*, since S_0 acts from C to o and is to be *replaced* by L and V_1; at B reaction *upwards*, since P_2 acts up, and following round, S_2 acts from o to C. *Both* reactions are *equal to a o*. At A then the support must be above, and at B below the beam. The shaded area gives the moments to pole distance H. Had we taken the pole in the perpendicular through o, S_0 would have been parallel with the beam itself. This is, however, a matter of indifference. The moment area may lie at *any* inclination to the beam. We also see here again the effect of a *couple* (art. 23). S_0 is simply *shifted* through a certain distance to S_2, parallel to S_0, and therefore the moment at any point between P_2 and B is *constant*. This is generally true of any couple, as we have already seen, Article 21, and may be proved analytically as follows:

Let the distance between the forces be a=A B, Fig. 22. Then for any point o, we have $P\times(a+B\,o)-P\times B\,o=P[a+B\,o-B\,o]=P\,a$. For o' between A and B, $P\times A\,o'+P\times o'B=P[A\,o'+o'B]=P\,a$.

So also for any point to the left, the same holds true.

Graphically the proof is as follows:

Fig. 22.



Decompose both forces into parallel components, Fig. 23. Then for any

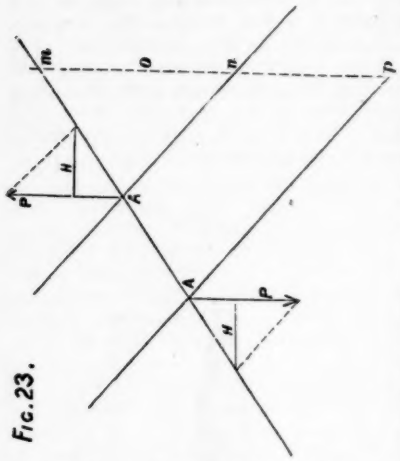


Fig. 23.

point, as *o*, we have the moment $M=H\times mn-H\times mp$ or $M=-H\times np$. But np is the constant ordinate between the parallel components A*n* and A*p*.

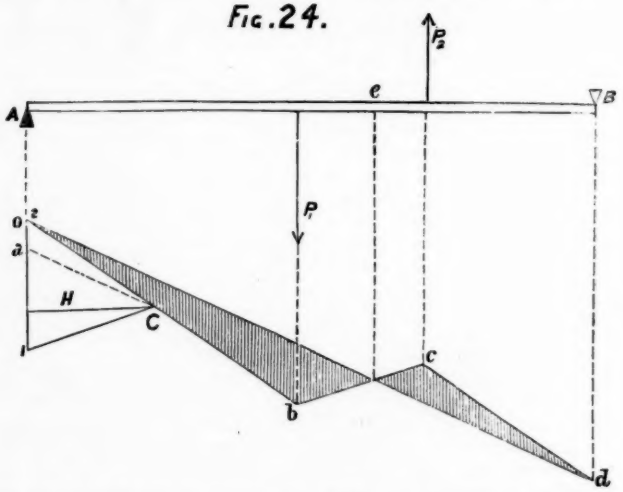
We see, therefore, by simple inspection, that the distance of P_1 and P_2 from the support B, Fig. 21, has no influence whatever upon the moment or strain in A B, provided the distance between the points of application remains the same, and that the moment at all points between P_2 and the support B is constant and a maximum. From B and P_2 the moments decrease left and right, and become zero at A and P_1.

40. BEAM WITH TWO EQUAL AND OPPOSITE FORCES BETWEEN THE TWO SUPPORTS.

Let the beam A B, Fig. 24, be acted upon by the two equal and opposite forces P_1 P_2.

Construct the force polygon *o* 1 2. Choose a pole C and draw C*o* C1 C2. Parallel to C*o*, draw the first side of the equilibrium polygon to intersection with P_1; then parallel to C 1 to P_2, then parallel to C 2 to *d*. Join *d* and *o*. Parallel to this draw C *a* in force polygon. Then *o a* is the vertical reaction at A, which acts upwards, since it must with C *a* *replace* C *o*, and C *o*, when we follow

Fig. 24.



round from *o* to 1 and 1 to C, acts from C to *o*.

We have the same vertical reaction at B, but here, since we must follow from 1 to 2 and 2 to C, C 2 acts from 2 to C, hence the reaction at B is downward.

We see at once that at a certain point *e* the moment is zero. Left and right of this point the moment is positive and negative. At the point itself we have a *point of inflection*, and here, since the moment is zero, there is *no strain*. At

b and *c* the moments are greatest; here the beam is most strained, and at these points, therefore, are the cross sections of rupture. Here again, if we had taken the pole C in the perpendicular through *a*, the closing line of the polygon *o d* would have been horizontal. It is, however, indifferent at what inclination *a d* may lie, but we may if we wish make it horizontal *now*, and then lay off from its new intersections with P_1 and P_2 along the directions of these forces, the ordinates already found at *b* and *c*, and join the points thus obtained with the ends of *o d* (*i.e.*, with its intersections with the verticals through the supports). The ordinates of the new polygon thus found will be for any point the same as before, and will also be perpendicular to the beam.

[*Note.*—Had we taken the forces precisely as above but in *reverse order*, the force line would be reversed, and we should have *o* and 2 in place of 1, and 1 in place of *o* and 2; that is, in place of C 1 we should have C *o* and C 2. Constructing then the equilibrium polygon by drawing a line parallel to new C *o* to intersection with new P_1, then parallel to new C 1 to intersection with new P_2, then parallel with new C 2 to intersection with vertical through B, and finally joining this last point with intersection of the first line drawn (C *o*) with vertical through A, we have at first sight a very different equilibrium polygon. This new polygon will consist of *two* parts. If the ordinates in one of these parts are considered positive, those in the other must be negative. The *difference* of the ordinates in these two portions for any point, will give the same result as above. This, by making the above construction, the reader can easily prove.]

41. Many other problems will readily occur, which may in a similar manner be solved. The weights may have any position, number and intensities desired; in any and every case we have only to construct with assumed pole distance the corresponding equilibrium polygon, and we obtain at once the moments at every point. By the use of convenient scales, numerical results may be obtained which may be checked by calculation, and the practical value and accuracy of the method thus demonstrated.

The above principles will be sufficient for the solution of any such problem which may arise, and we shall therefore content ourselves with the above general indication of the method of procedure, and pass on to the consideration of a few cases where the above needs slight modification, and which, from their practical importance, and the ease with which they may be treated graphically, seem worthy of special notice.

1ST. BEAM OR AXLE—LOAD INCLINED TO AXIS. [Fig. 25.]*

We have here simply to draw the "closing line" A C parallel to the beam

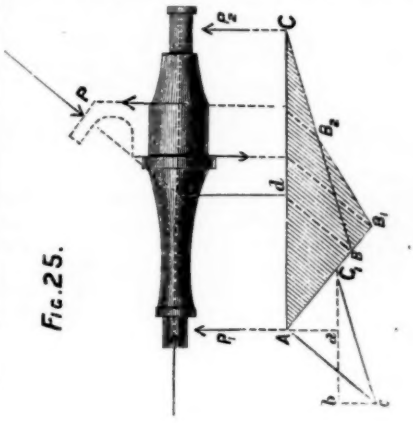


FIG. 25.

or axle. From *d* draw *d* B parallel to the forced P, then draw A B in *any* direction at pleasure, and join B C. We have thus the equilibrium polygon ABC, the ordinates to which, as *d* B, *parallel to the force* P, will give the moments, *provided we know the corresponding pole distance.*

But this can easily be found. As we have already seen, the force polygon being given, the equilibrium polygon may be easily constructed. Inversely, the equilibrium polygon being given, the force polygon may be constructed. Thus, from A draw A *c* equal and parallel to P, and then draw *c* C_1 parallel to B C. A *a* and *b c* are the vertical reactions at P_1 and P_2; *a b* is the horizontal component of the force which must be resisted at one or both of the ends; and the moments at any point are given by the

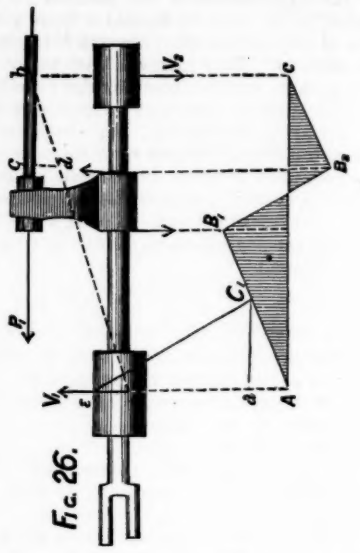
* See *Reuleaux-Der Constructeur.*

ordinates parallel to P multiplied by the perpendicular distance from C_1 to A *c*. If we suppose the force P, as in the Fig., as causing two opposite vertical forces, instead of acting directly upon the axis, we have only to prolong A B to B_1 and join B_1 B_2, and then the ordinates of A B_1 B_2 C parallel to P or A *c*, multiplied by H (perpendicular distance from C_1 to A *c*) will give the moments.

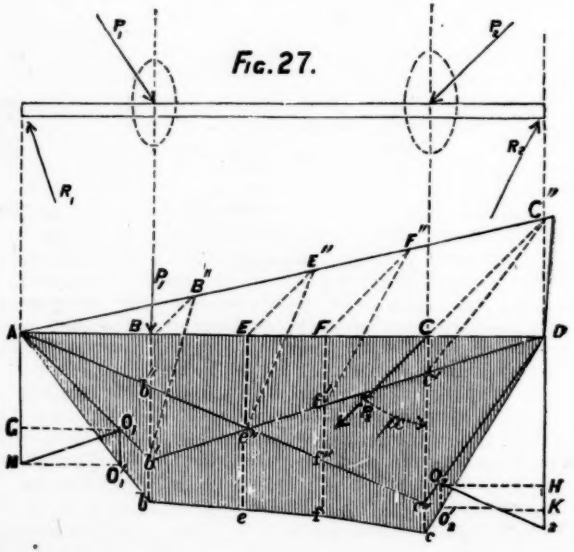
2D. FORCE PARALLEL TO AXIS, FIG 26.

We have an example of this case in he "bayonnet slide" of the locomotive engine.

We have here two pairs of forces, the reactions V_1 and V_2 and the forces over B_1 and B_2. The points of application of these last, change of course periodically, but for any assumed position the moments are easily found. Thus draw A B_1 at pleasure, and C B_2 parallel to it, and join B_1 B_2 and A C, and we have at once the equilibrium polygon. To find the corresponding *force polygon*, suppose P_1 applied at *b*, and join *b* with the other support. Make *b c* equal to P then *c d* $=V_2$. Say off then A *a*=*c d*=V_2 and draw *a* C_1, which is the *pole distance*. Draw C_1 *e* parallel to B_1 B_2. Then A *e* and *e* A are the forces acting over B_2 and B_1, and A *a* is the reaction V_1. The case is, indeed, precisely similar to that in Art. 40.



[*Note.*—The moment area should properly be turned over upon A C as an axis, so that A *a* should be laid off and *e* fall *below* A. This can, however, cause no confusion.]



The application of the method to car axles,* crane standards, and a large number of similar practical cases in Mechanics is obvious. The formulæ for many of these cases are too complex for practical use; in some no attempt at investigation of strain is ever made, the proportions being regulated simply by "Engineering precedent" or rules of thumb. Those familiar with the analytical discussion of such cases will readily recognize the great practical advantages of the Graphical Method.

3D. BEAM OR AXLE ACTED UPON BY FORCES LYING IN DIFFERENT PLANES.

The analytical calculation in such a case is of considerable intricacy, but by the graphical method, on the contrary, the difficulty of investigation is scarcely greater than before.

Thus, let Fig. 27 represent a beam acted upon by two forces P_1 and P_2 *not in the same plane.*

First, we draw the force polygons A O_1 M and D O_2 for the forces P_1 and P_2, having both the *same* pole distance G O_1 $= O_2$ H, the pole O_2 being so taken that the closing lines of the corresponding polygons A b'' D and A C'' D coincide. This is easily done, as if the closing line of the second polygon for any assumed position of O_2 (O_2 H being equal to G O_1) does not coincide with A D, the ordinate at C'' can be laid off from C and A C'' D thus found in proper position, and then the pole O_2 can be located. It will evidently be at the intersection of O_2 O'_2 with C'' D.

The two force polygons being thus formed, we construct the polygon A C'' D by drawing lines B B'', E E'', C C'', etc., so that their angles with the vertical shall be equal to the angle between the planes of the forces, and making them equal to the ordinates B b'', E e, F f'', etc., respectively. Join b' B'', e' E'', f' F'', c'' C'', etc., and lay off the ordinates B b, E e, F f, C c, etc., respectively equal. The ordinates to the polygon thus obtained, viz.: A b e f c D multiplied by the *pole distance* O_1 G or O_2 H, give the moment at any point. A b and c D are straight lines, b e f c is a curve (hyperbola). If we drop verticals through O_1 and O_2, and draw the perpendiculars O'_1 M, O'_2 K, A M is the reaction R_1, and D K the reaction R_2, both measured to the scale of the force polygon. Their

* *Reuleaux-Der Constructeur*, p. 215-222.

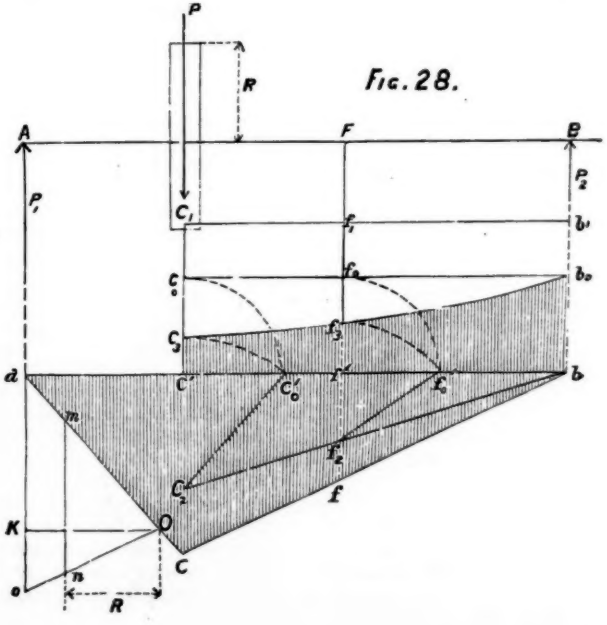


Fig. 28.

directions are found by the composition of A G and H_2 and D H and G M respectively, under the angle of the forces.

4TH. COMBINED TWISTING AND BENDING MOMENTS.

In many constructions pieces occur which are subjected at the same time to both bending and *twisting* moments. Both can be represented and given by moment areas. Thus, Fig. 28 represents an axle turning upon supports at A and B and having at C a wheel upon which the force P acts tangentially. We have then a moment of torsion $M_t = P\,R$ and reactions $P_1 = P\frac{s}{a+s}$ and $P_2 = P\frac{s}{a+s}$, s being the distance of P from B, and a of P_1 from P.

Let the bending moments be represented by the ordinates to the polygon $a\,c\,b$, then laying off $a\,o$ equal to P and drawing o O parallel to $b\,c$, we find the *corresponding pole distance* O K, and the reactions P_1 and P_2 equal to K a and O K respectively.

Now, in the force polygon s O a o thus found, at a distance from O equal to R, draw a line $m\,n$ parallel to P. This line $m\,n$ evidently gives *for the same pole distance*, the moment of torsion P×R. Laying off $C'\,C_1 = b\,b_1 = m\,n$, we have the torsion rectangle $c_1\,b_1\,b\,c'$.

Now the combined moment of torsion M_t and bending M_b $\frac{8}{8}\,M_b + \frac{8}{8}\sqrt{M_b^2 + M_t^2}$.* We make then $C'C_0$ equal to $\frac{8}{8}\,C'C_1 = \frac{8}{8}\,mn$ and CC_2 equal to $\frac{8}{8}\,CC' = M_b$, and draw $C_2 b$. Then any segment of any ordinate, as ff_2 is $\frac{8}{8}$ of ff'. Revolve now $C'\,C_0$ with C' as a centre, round to C'_0 and join $C'_0\,C_2$. Then $C_2\,C'_0$ is equal to $\frac{8}{8}\sqrt{M_b^2 + M_t^2}$, and therefore with C_2 as centre revolving $C_2\,C'_0$ to C_2, we find the point C_2, C C_2 being equal to $\frac{8}{8}\,M_b + \frac{8}{8}\sqrt{M_b^2 + M_t^2}$. In the same way we find any other point as f_2, by laying off $f\,f_0$ equal to $f\,f_0$, joining f_2 and f_0, and making $f_2 f_3$ equal to $f_2 f_0$. The line $C_2 f_2 b_0$ thus found is a hyperbola, and the ordinates between it and $b\,c$ give the combined moments [for pole distance O K] at any point.

[*Note.*—We suppose the axle to turn freely at A, and the working point or resistance beyond B; hence the moments left of the wheel are given by the ordinates to $a\,c$.]

* *Reauleaux-Der Constructeur*, p. 52, Art. 18.

STREETS.*

By B. H. CUNNINGHAM.

From "Engineering."

THE object of this paper is to describe the street coverings now most used, and to show their relative advantages and defects. But before we can weigh these fairly, or form reasonable opinions regarding them, we must have distinct ideas about the nature of roads in general, and we must find out what a good road really is. I shall, therefore, in the first place endeavor to make a comprehensive theory of roads, and in order to do this shall enumerate and describe the qualities which a good road ought to possess. We shall thus see what ends road-makers should aim at, and what difficulties they have to overcome. Secondly, I shall proceed to apply this general theory of roads to one particular case, viz., streets, dividing all kinds of modern streets into four great classes:

I. Macadam, and Macadam Concrete Sts.
II. Streets paved with stone setts.
III. Streets paved with wood.
IV. Streets paved with asphalt.

Thus you may see that having found out what a road is, our attention will be confined to the roads now made in this country, or in countries like it in civilization and physical features;—and further, that it will be confined to these in or near cities where the traffic is large and heavy, that is to say, to streets.

Having adopted these limits, we will not enter upon such subjects as the ancient and modern history of roads—the principles which guide their exploration—the methods of construction adopted in remote colonies and western states—or the working of our own highway

* Paper read before the Edinburgh and Leith Society.

Acts. Passing references will however be made to history, whenever it affords us useful hints, either in the way of example or warning. Finally, I must explain that this paper is no record of original observation or experiments. Still, I venture to hope that it will not be found uninteresting or useless. In the first place, the theories of some of those who have made roads well, or had them long under their charge, are stated and examined; so that, if possible, we may compile a sound and comprehensive theory of our own. Secondly, a good many facts have been collected from various scattered sources and grouped together, so that they may be easily referred to and compared. The consideration of these facts will, I hope, show the relative advantages of the four kinds of streets already mentioned. Having thus cleared and defined our ground, we may now endeavor to answer the question, What is a good road?

It is not easy to do this in a single sentence, therefore it seems best to adopt the method already indicated and enumerate the qualities which a good road ought to possess. These are:

I. *Surface Hardness.*—Wheels and horses' feet must not sink or cut into its substance. Brittle hardness might be enough to prevent this, but a road surface must have toughness. It must stand the wear caused by the rolling or grinding of the traffic, also the blows from horses' hoofs, and the jolting and concussions of vehicles.

II. *Smoothness.*—When this quality is conbined with hardness, we at once obtain five things which are of great value to all connected with roads.

1. *Minimum Wear of Surface.*—It is a euphemism to speak of a carriage rolling along a road, as the real motion is of a very different kind. Let us watch an empty cab, while being driven quickly over an ordinary granite pavement. This is certainly an extreme case, but for that reason it shows clearly the action which takes place. It can easily be seen that the cab advances by a series of small jumps, and gives pretty sharp blows to the setts which it happens to strike. This is caused by inequalities in the road, particularly at the joints of the stones, and the same thing happens more or less in connection with every kind of traffic, no matter how heavy and slow; and on every kind of pavement, no matter how hard and smooth. The stones are thus ground or chipped away, besides being gradually knocked out of position and forced down into the substratum. Vehicles act chiefly, though not altogether, on the surface of the setts, but horses principally chip off their edges, and give them a rounded shape, by their endeavors to get a firm foothold. This is proved by the fact that between tramway rails, where the setts are chiefly exposed to the action of hoofs, they become more rounded on the top than those subjected to general traffic in adjacent parts of the street. On a smooth, hard surface, there is comparatively no jolting and little abrasion, and, by reducing these, we shall evidently save material and lengthen the period during which the road will remain in good form.

2. *Minimum Wear of Vehicles.*—The wear of vehicles must no doubt be an important item, though it is not easy to estimate. Jolting is at least as bad for the vehicle as for the road, and a considerable sum can be saved to the community by making hard, smooth roadways.

3. *Minimum Noise.*—This becomes a desideratum where the traffic is incessant.

4. *Minimum Draught.*—The effects of different degrees of hardness and smoothness on draught have often been experimentally determined, and the results practically agree, though obtained in different places and at various periods. A few of them may be referred to here, as they conclusively show the importance of these qualities. At the Royal Agricultural Society's Bedford Show last summer, the average draught of seventeen carts was found to be 39 lb. per ton on a macadamized road, at $2\frac{1}{2}$ miles per hour, and 140 lbs. per ton on a field at $2\frac{3}{4}$ miles per hour. Sir John MacNeil's results are rather higher, being 46 lb. to 65 lb. per ton on macadam, and 147 lb. per ton on gravel; but such small differences need not surprise us, when we consider the impossibility of making the experiments in precisely similar circumstances. Other instances might be given, in which it was found that the draught was increased from 3 to 5 times, by allowing roads to get into bad order, or by putting on new metal.

For the sake of comparison, it may be mentioned that the draught on a railway, which is merely a very perfect kind of road, would probably not exceed 10 lbs. per ton. Now, diminished draught means, that each horse is enabled to do more work, or to do the same amount of work, with less exertion and straining, and, in either case, there will be considerable saving to their owners. Such considerations prove the advantages of having the least possible draught, and show that it can be obtained by making road surfaces hard and smooth.

5. *Cleanliness.*—We have seen how rough roads are worn away by the traffic. Now, the small *débris* ground and chipped off the material, forms mud or dust, according to the state of the weather. To a certain extent mud is also caused by the subsoil working up through the joints of the stones. But however caused, their evil effects are manifold. Dust, especially in cities, often consists to a large extent of poisonous organic particles, which people are apt to inhale. The poor cannot keep their houses clean if they are constantly going out and in with dirty clothes and boots; and we all know that cleanliness is essential to social well-being. The rich suffer too. Their furniture is often destroyed by the dirt. Shopkeepers also frequently lose considerable sums, owing to the injury it does to their goods. Moreover, mud is very injurious to the road itself. A clean road wears better than a dirty one. From what has been said, it will be seen that the quantity of mud carted away is a measure of the rate at which the material of the road is being consumed. Thus, in Dublin at one time the quantity of mud annually removed was greater than the quantity of metal annually laid on; and accordingly, the surface of the roads was gradually being lowered. Again, when machine-sweeping was introduced into Manchester, owing to the reduced cost certain streets were swept three times as often as formerly, but the quantity of mud removed was only 4 per cent. greater; and in other towns, where the machines were used and the number of sweepings increased, the quantity of mud removed was actually diminished. Mud keeps the road damp, and this softens the subsoil, making it work up through the joints, and thus increasing the amount of dirt to be removed. Besides, when the subsoil is in this damp, soft state, the setts are readily forced into it, and the road-surface becomes uneven and full of holes. By keeping the road wet, mud also facilitates the grinding down of the stones, as a supply of water materially aids this process. But we must return to our list of qualities.

III *Solidity.*—A road must have a firm substance, capable of resisting the weight of the traffic. A certain amount of bulk is necessary, because a pressure may crush a 3-in. cube, which would have no effect on a 12-in. one. The theoretical pressure of loaded vehicles does not vary much. Telford (probably founding his opinion on the practice of the time), thought it should not exceed 1 ton on each wheel, the tyre being 4 in. wide; that is 5 cwt. per inch of width of tyre. This opinion seems still to be held by cart makers, for at the recent Bedford Show, the average weight per inch of tyre was 4½ cwt., the maximum and minimum being respectively 3½ and 5½ cwt. The weight of road rollers is about the same. Aveling and Porter's 30-ton roller exerts a pressure of about 5¼ cwt. per inch of width, and that of their 15-ton roller is only about 4 cwt. per inch of width. Pickford's vans and London omnibusses are exceptionally heavy, being sometimes loaded up to 8½ cwt. per inch. Such are the calculated pressures in some instances, but it is difficult to say to what extent they may be increased, owing to tyres becoming convex.

IV. *Elasticity.*—The importance of this quality is perhaps not obvious at first sight, and as it is yet scarcely sufficiently recognized by road makers, I shall devote a few minutes to its consideration. Macadam thought that a certain amount of elasticity was esential to the endurance of his roads. He preferred a soft foundation, and noticed that a part of the road from Bridgewater to Cross, which was laid on a bog, and actually shook when a carriage went along it, consumed less metal, and was more easily kept in repair, than neighboring portions laid on limestone rock. He thought that a road was to some extent an arch, and supported the pressure of the traffic by its capacity of resisting inclined

strains, as well as by its density. Telford, on the other hand, insisted on having a solid foundation, and seemed to ignore the advantages derived from elasticity. He held that a road was only a hard, solid body, which would prevent the wheels from sinking into the ground. Telford's system has been more generally adopted than Macadam's, though I think experience shows that the latter was right in endeavoring to make elastic roadways. It is now generally admitted to be most important that road coverings should possess this quality, and engineers have possibly come to this conclusion by observing railways. I have already remarked that a railway may be considered a very perfect road. The rails are hard, smooth, and solid, and carry enormous loads, moving at great speeds. Accordingly, whatever qualities are found to secure permanence and endurance in rails, will probably do the same for road-metal and pavements, though they may be required in a much less degree. Now, no one doubts the importance of elasticity in a permanent way. The only question seems to be, whether rails, and even wheels, should be made a great deal more elastic than they are. The Committee of American engineers on Rails, in their report, recently published, point out many ways in which it benefits the track, and I shall quote one or two of their remarks. "Too much stiffness diminishes the longevity of the rail. Inelastic road-beds are among the causes of rails becoming unfit for service. When the stem is too thick, the rail is too rigid, and this increases the wear on the head, and the liability to break. Rails in winter often break, because the bed is frozen hard." So far the report. But besides all this, it has been observed that rails laid on soft ground, such as a bog or an embankment, are more easily kept in good surface, and are easier to run on, than those which are laid on a hard foundation, such as a rock cutting.

Now, all these experimental facts prove that, as far as railways are concerned, elasticity is absolutely necessary.

But why? We have seen its effects, but how does it produce them? According to one authority it "absorbs the effects of the blows of the wheels," or in the words of another, "it neutralizes the vibration arising from the impact of imperfect cylinder rolling on imperfect planes." And this is no doubt the case, though the precise nature of the concussion, or impact, may not be well understood. The empty cab jolting along granite may serve as a very rude specimen of the kind of action which takes place on a railway. Probably it is caused by the combination of three things,—1st, high speed; 2nd, imperfect workmanship, owing to which neither rails nor wheels are quite smooth, and the latter are badly balanced; and 3rd, the elasticity of the materials employed. I fear the first two are not likely to be removed, and it is certain that the last never will. This concussion, therefore, appears to be a thing which we cannot get rid of, and which it is better and cheaper to meet, by giving considerable elasticity to rails and wheels, than by attempting to give them great theoretical perfection, that is to say, perfect smoothness and rigidity. Such an attempt would involve a large first cost, not to mention the cost and difficulty of maintenance. But whatever its nature, we have a rough idea of its amount, from the experiments of the Railway Iron Commissioners, in connection with wrought-iron bridges. They found that rapid motion might be supposed to add about one-third to the load, and acting on these results, it is the universal practice to make the working strain one-third or one-fourth of the breaking strain, according as the structure is to be free from or subject to vibration. In short, we find that Macadam early observed the value of elasticity in a road-covering, but that his ideas on this subject have not till recently been much acted on. We saw the importance attached to elastic rails by permanent way authorities, and having noticed these facts, we tried to ascertain the reasons which in the nature of things cause them. These we found to be great speed, imperfect workmanship, and the inherent elasticity of our materials. We therefore came to the conclusion that we cannot get rid of these causes which make elasticity essential to the endurance of permanent way, and that we ought to try to neutralize the unavoidable impacts, by giving more of that quality to rails and wheels, rather than by attempting to make them perfectly smooth and rigid.

Finally, all this applies in a less de-

gree, but still a perfectly sensible degree, to roads. We are therefore led to suppose that elasticity will prove beneficial to road metal and pavements. This has been found to be the case, and the more this principle is acted on, the more this result will be confirmed. The chief benefit of elasticity is seen in the road itself; indirectly, however, it is advantageous to carriages, and this also can best be seen in railways.

V. *Durability.*—The importance of this is so obvious, that hardly anything needs to be said about it. Repairs are not only costly, but in crowded thoroughfares they inconveniently obstruct the traffic.

VI. *Rapidity of Construction*, so that it may be quickly laid down, and soon opened for public use. One concrete road was shut up for a month, that it might have time to set thoroughly. But such a thing could never be allowed in a crowded thoroughfare.

VII. *Capability of being easily lifted*, to give access to water and gas pipes, and sewers. This operation should be executed quickly, so as not to interfere with the traffic, and the roadway should not be liable to receive injury from having a part cut out and replaced. The introduction of subways has enabled us to dispense with this quality in some towns, but there are still many places where it is of great importance.

VIII., and lastly, *Roughness.*—A road should be sufficiently rough to afford foothold for horses.

Such are the qualities which, when combined, make a good road. Now, in looking over our list, we cannot but be struck by the fact that some of them appear to be incompatible with others. Thus, it is not obvious how a road can be hard, solid, and durable, as well as elastic and easily taken up for repairs. Nor is it evident how smoothness can be combined with the roughness necessary to give secure foothold. No doubt these requisites are opposed to each other, and herein lies the difficulty of making a satisfactory pavement. But this is not an exceptional difficulty. On the contrary, engineers continually have to sit in judgment on the relative importance of conflicting and incompatible objects. In such circumstances they must trust to practical sagacity, or to a kind of intellectual instinct not easily described. By means of this, even more than by their perseverance and energy, the founders of our profession accomplished their great works, though without many of the advantages we possess. But our advantages cannot make up for the want of this moral faculty, and unless we diligently cultivate it, we shall not be able worthily to follow in their steps.

On examining our list of qualities more minutely, I think we shall notice that the interests of those who make and maintain roads are identical with the interests of those who use them, or in other words, that the interests of trusts and vestries are the same as those of the public. A road and wheel may be considered two parts of one machine, and it is usually advantageous for all parties concerned that a machine should work as easily as possible. Referring again to railways for a moment, we shall see this more clearly. Rail and wheel are obviously two parts of one machine, and accordingly it is found that whatever does harm to the one injures the other also. Thus, whenever the platelayer complains that a particular engine is destroying his road, the driver of that engine is sure to complain that it is being destroyed by the road. But we shall confine our attention to trusts and the public. The latter body does not like noise, nor dust, nor mud, nor unrolled metal. Neither should the former. For noise is simply an audible sign that a process of hammering and grinding is being vigorously applied to the road; and the presence of mud or dust clearly shows that its material is being rapidly consumed. These things indicate bad construction, either in the arrangement or choice of materials. It has been already remarked that clean roads are more economical than dirty ones, and that constant sweeping effects a saving on the cost of maintenance. Rolling will be referred to further on, but I may here state that as well as making a smooth surface, it saves a considerable proportion of the cost of repairs. Roads of some kind are a necessary of life, but good roads are not an expensive luxury. On the contrary, they are the cheapest form in which this indispensable means of communication can be procured.

I shall now proceed to the second part of my subject, and describe very briefly the four modern kinds of roads, comparing the relative advantages and defects of their respective coverings, and calling your attention to the more important details of construction.

I. *Macadam and Macadam Concrete.*—Roads of this kind were introduced by Macadam and Telford, and I have already stated their respective theories on this subject when treating of elasticity. Telford's method of construction has been most generally adopted, not I think because it is in itself the best, but because it is the easiest. The success of Macadam's chiefly depends on very careful workmanship, and therefore it has perhaps hardly received fair play in other people's hands, though it appears to have worked well when carried out under his own supervision. But, without further reference to history, I shall now shortly indicate the details of construction, which in the present day seem to me of most importance. I think, then, in the first place, that Telford's paved foundation is injurious, because it deprives the road of elasticity, and is in fact a kind of nether millstone, upon which the covering is ground down. The top metal must be carefully selected. It should be tough and hard, not brittle, and not liable to disintegration by the weather. It should be broken evenly, because large stones are liable to be worked upwards by the agitation of traffic, and leave spaces, which hold water and prevent consolidation. The pieces should be cube-shaped, because this is the strongest form, enabling them best to resist the weight of the traffic and the splitting effects of frost. Machine broken metal, when first introduced, was very defective in this respect, the pieces being split into long thin rectangles, but this fault has now been to a great extent remedied. If the metal is too small, the wheels will sink into it; if too large, they cause jerks, and so break it. Macadam thought that the cubes should weigh not more than 6 oz., or, what is the same thing, should pass through a 2½ in. ring, and this size has been generally adopted, so we may assume that it is about right. It would be possible, however, to consolidate larger metal if the roads were rolled, and this would make them stronger, as well as save labor. Blinding ought certainly to be applied. There is a little confusion about this term, some writers using the word "blinding," apparently from an idea that it better expresses what is meant. "Blinding" is however precisely the same word as "blending." To blend originally meant to mix, and "blind" has acquired its ordinary meaning from the fact "that mixture causes obscurity." "Blinding," therefore, when it denotes the sand or fine gravel put upon a road, is used in its original sense, and implies that the material so named should be thoroughly mixed amongst the stone, so as to fill up the empty spaces. This is exactly what it is meant to do. The interstices of the covering must be filled up before the road can become perfectly hard and solid. And this must either be done by supplying sand, or by allowing the traffic to grind sufficient fine stuff out of the metal. If not sufficiently blinded, the stones roll about and get rounded, which prevents their ever binding together properly. If blinded too much, the road soon partially consolidates, but is always soft, and extremely muddy and dusty, because it consists to a large extent of sand. A rough notion may be formed as to the proper quantity of blinding to apply. It depends chiefly upon the amount and effect of rolling, and must be determined by experience, but the following reasoning may guide us generally. In a layer of road metal there are voids to the extent of 40 per cent. By rolling, at least half of these interstices would be filled up, owing to the pieces of metal being pressed together. Twenty per cent. of the metal would therefore be sufficient blinding, and in fact it is usual to supply from 17 to 25 per cent. But it will be seen that unless rolling is attended to, 20 per cent. of empty space will remain, which must be filled up by attrition from the metal. Two of the advantages derived from rolling have been already referred to. The whole subject is of great importance and interest, and is very fully discussed in Mr. Paget's report to the Metropolitan Board of Works, on the Economy of Maintenance which it produces. For further information I must refer you to this pamphlet, and can only here state, that by steam rolling 50 per cent. of the annual cost of maintenance is saved,

chiefly owing to the great reduction in the quantity of metal consumed, while at the same time the work is done more rapidly, and is of better quality.

Macadam roadways have many good qualities, but there is one most serious objection to their use in towns. The metal wears so rapidly, that they are always covered with mud or dust, and can only be maintained in good order by constant and expensive repairs. In London it is the practice to lay down pavement whenever the annual expense of maintaining macadam reaches 10d. per superficial yard. In these circumstances the first cost of paving is always repaid in a few years, by the reduced outlay required in maintenance.

Obviously this system can be modified in various ways, by adding cement to the metal. Thus, either the foundation or the top metal, or both, can be made into concrete. This has frequently been done. The roadway of part of George IV. bridge is an old example of macadam concrete. This was laid in 1866, and seems to have stood well, but is now much worn on the surface, owing, I think, to its great hardness and rigidity. Mr. Proudfoot, the engineer to the City Road Trust, by means of the steam roller and a machine for mixing the cement—also by careful attention to the selection of metal and workmanship, has succeeded in producing much better roads of this kind. I fear, however, that they are deficient in elasticity, and would therefore wear rapidly if exposed to heavy traffic. The long time which the cement takes to set—generally about a month—during which the street must be shut up, is also a serious disadvantage. But these objections may not be important in many cases.

On the whole, we may conclude that macadam and macadam concrete roadways, although they may answer well in secondary streets, should not be laid in main thoroughfares. We may also conclude that neither this system of road making nor any development of it, is likely to produce the street of the future.

II. *Stone Pavements.*—Macadam has hitherto been generally superseded by granite pavement, when its maintenance became too costly. Little need here be said about the construction of these pavements, because residents in a town have frequent opportunities of observing the whole process. A few points may however be noticed. A good solid foundation is essential, otherwise the setts get forced down into it, and holes are formed in the street surface. The more holes there are, the greater is the wear of the setts, owing to the chipping and attrition caused by the traffic. Water also lodges in them, and tends still further to soften the foundation. The stones themselves should not polish easily, but remain rough on the surface. They are usually rectangular blocks, 8 in. to 16 in. long, 7 in. to 9 in. deep, and 3 in. to 5 in. broad. The smaller thickness gives the best foothold, but may weaken the sett, and the ordinary size is 4 in. to 5 in. Pavement of this kind is sometimes laid on concrete, and the joints fronted with cement and sand. This makes a very firm road. Bituminous concrete has also been used with stone setts. The chief objections to streets of this kind are their slipperiness, particularly when only a little wet, and the noise; also, I think, the want of elasticity. The effects of the absence of this quality are seen, whether the foundation is hard or not. If hard, the setts are rapidly worn away and rounded. If soft, they are driven down into it, and the surface is destroyed. An attempt was made to remedy this defect at Euston Station about 1843, by Mr. Taylor. Mount Sorrel granite setts only 3 in. or 4 in. deep, 3 in. wide, and 4 in. long, were laid on a carefully prepared foundation, consisting of three layers of gravel, each 4 in. thick, and carefully rammed. The setts were dressed and squared, and when laid were rammed with a 56-lb. wooden rammer. This pavement was found to be very impervious to wet, and very quiet, and, owing to its elasticity, the stones did not polish or wear much. Unfortunately the success of this method of road making, like Macadam's, depends too much on mere workmanship, and, when applied to an ordinary street, it failed. Part of Watling-street was paved in this way, and stood well till destroyed by sewerage operations. Granite pavement has no doubt been a most useful kind of street covering, but it is hardly up to the standard of excellence demanded by the civilization and luxury of the present day. I must say I think the public are not un-

reasonable in their demands, and have a right to ask for something better, considering the progress now made in all departments of engineering.

III. *Wood Pavements* have been tried in London at various periods since 1839. The best kind is that of the Improved Wood Pavement Company. It consists of fir blocks 3½ in. wide, 10 in. long, and 6 in. deep, set on end upon a double flooring of fir planks laid crosswise. The blocks are laid touching one another, so as to key across the street, but at the sides they are kept apart by ¾-in. fillets nailed to the planks. All the timber is well pitched, and the joints are grouted with some kind of bituminous concrete. Specimens of this roadway may be seen in Queensferry-street, and Forrest-road

IV. *Asphalt* was introduced into London for paving purposes in the year 1869. Several varieties have been tried, but the compressed asphalt of the Val de Travers Company has been found to be superior to all others, and is the only one which need engage our attention. It is a natural product, found in Switzerland, and the following is the method adopted in constructing pavements of it: A concrete foundation is first made, and on this the asphalt in the form of a heated powder is laid, to the thickness of 2 in. or 2½ in. Specimens of this kind of roadway may be seen in Kirkgate, Leith, and Gordon-street and Hope-street, Glasgow.

Wood and asphalt pavements are in several respects superior to granite. Much less mud and dust is formed on them, and they are comparatively free from noise. They are also safer, except when thoroughly wet. I am not aware that granite is in any respect superior to either of them. Even if they should turn out to be more costly, owing to their requiring repair more frequently, and having to be renewed sooner, I think the advantages already mentioned will more than compensate for the extra price. Only long and extensive experience can settle this point satisfactorily, because many indirect benefits are secured by their use, which it is not easy to estimate in money;—and there are many expenses connected with all pavements which are not usually included under the head of maintenance. On the whole, it seems probable that either wood or asphalt is destined gradually to supersede granite as a paving material, at least in large and wealthy towns.

It therefore only remains for us to find out which of them makes the best, or, to quote the *Pall Mall Gazette*, the "least objectionable" road surface. Mr. Haywood has fully reported to the Commissioners of Sewers of the City of London, as to the relative advantages, together with the probable expense and durability of these pavements. In 1873 he made a very extensive series of observations, in order to ascertain their relative safety. It is, however, difficult to make observations on different streets in such a way as to admit of their being fairly compared with one another, because safety varies so much with the weather, and also depends to some extent on the gradient of the street, the speed of the traffic, the state of surface repairs, and cleanliness. But, allowing for all these modifying influences, he found that wood is safer than asphalt, as not only fewer accidents occur on it, but those which do happen are of the kind least injurious to horses and obstructive to traffic.

Further, Mr. Haywood considers that wood is the most quiet, but also the dearest; that they both can be kept equally clean, and will probably be found equally durable. That they can be laid and repaired with about equal facility but that the best repairs can be made in asphalt.

The general impression left in reading the report, is that except as regards safety, there is not much difference between them. Wood is, however, about twice as safe as asphalt. It must also be kept in mind that the cost and durability is estimated from the tenders of the contractors, not from actual experience.

So much for the practical results. Let us see which of these two pavements is likely to endure best, judging from theoretical considerations alone. Wood pavement is constructed according to Macadam's principles, asphalt according to Telford's. Wood is laid on a comparatively soft foundation, and the whole roadway forms a kind of elastic arch, which partly resists vertical pressure, by distributing the thrust horizontally through its entire substance. In asphalt roadways, on the other hand, the concrete foundation may be considered the

real road, the asphalt being merely a sort of protection, which gives a smooth surface, and can be easily renewed as it is worn away. But this combination is, I fear, devoid of elasticity. Elasticity is without doubt essential to the permanence of a roadway. This quality certainly appears to be secured in improved wood pavements, though not in asphalt. But it may be contended that the asphalt covering has in itself sufficient elasticity, and that it acts like a sheet of vulcanized india-rubber. Possibly a concrete bed covered with a sheet of vulcanized india-rubber might form a good road. I think a less yielding surface is desirable, and that elasticity of form is likely to give better results than mere elasticity of volume. For these reasons I venture to think that improved wood pavement will ultimately be found superior to Val de Travers asphalt, and that the introduction of the former has been a decided step in the right direction. I also think that we may look for further improvements in modifications of this system, and that a roadway having the requisite surface qualities combined with elasticity of form, will always be superior to one whose chief recommendation is mere solidity.

I fear I have wearied you by the great length of this paper. My excuse must be the extensive nature of the subject, and I can only assure you that much important matter has been unavoidably omitted. For instance, no reference has been made to various improved systems of street sweeping and watering. I have thought it better to confine statements of cost to a tabular appendix, so as not to confuse the text with numerical statements, also that the figures may themselves be more easily compared. Finally, I wish to take this opportunity of thanking Professor Fleeming Jenkin, Mr. Proudfoot, and Mr. Graham Smith for assistance which they have kindly given me in various ways.

COST OF ROADS AND STREETS IN DISTRICTS NEAR EDINBURGH, GLASGOW, AND CARLISLE, ALSO IN LONDON.

I. *Macadam and Macadam Concrete:*

Country roads, 1861–1874, per sup. yd. 1s. 2d. to 1s. 6d.

Town roads, founded on shivers, or hardest stone:

	s.	d.
15 in. metal, 1871	1	9
16 in. " 1874	2	4
18 in. " 1873	2	11½

Whin metal, 2 in. to 2½ in.:
Average price, 1861–1874, per cub. yd. 4 10
Price in Edinburgh, 1874, per ton, 5s. 9d. to 7s. 3d.
Note.—One cub. yd. whin metal weighs 27 cwt., and contains 40 per cent. of voids.

In London:	s.	d.
Granite 5 oz. metal costs (1870) per ton	16	0

1 cub. yd. granite weighs 24 cwt.

Cost of maintaining macadam, per sup. yd 1½d. to 3s. 3d.: average	0	6
Wear on Westminster bridge per ann.	5½ in.	
Ditto, ordinary,	do. 1 in. to 2 in.	

Note.—When maintenance of macadam reaches 10d. per annum, pavement is cheaper.

Macadam Concrete in Edinburgh:	s.	d.
Mitchell's, 1866, per sup. yd	6	8
Proudfoot's, 1874 "	9	0

II. *Stone Pavements:*

Granite on shivers, 1874, per sup. yd. 10s. to	12	0
Ditto, concrete, 1872, per sup. yd.	14	0

In London (averages):

Granite, on shivers, per sup. yd	18	0

Lasts for seven years.

Wear per ann., Aberdeen granite, ⅛ in.		
Cost of repairs per ann. per sup. yd.	0	3
Cost of pavement and repairs per ann., per sup. yd.	2	10

1.3 per cent. of first cost required for repairs, per sup. yd. per. annum.
Note.—In estimating the cost of granite pavements, allowance must be made for value of old stones.

III. *Improved Wood Pavement:*

London contracts. Company to maintain 1 year free, and 15 years at 1s. 3d. to 1s. 6d. per sup. yd. per ann.

First cost, per sup. yd. 16s. to	18	0
Cost of repairs and pavement, per annum, per sup. yd 2s. 2d. to	2	6½

Terms offered by company. Maintenance 1 year free, and 15 years at 9s. to 1s. 6d. per sup. yd. per annum.

First cost, per sup. yd. 15s. to	16	3
Cost of repairs and pavement per annum, per sup. yd. 1s. 7¾d. to	2	5

IV. *Val de Travers Compressed Asphalt:*

London contracts. Company to maintain 2 years free, and 15 years at 9d. to 1s. 6d. per sup. yd. per annum.

First cost, per sup. yd. 16s to	18	0
Cost of repairs and pavement per annum, per sup. yd. 1s. 7¼d. to	2	4½

Terms offered by company in Scotland. Maintenance for 2 years free, and each year after at 3d. to 9d. per sup. yd. per annum.

First cost, per sup. yd.	15	0
Cost of repairs and pavement for 17 years, per annum. 1s. 1¾d. to	1	6½

THE ECONOMIC USE OF BLAST-FURNACE SLAG.

By PERRY F. NURSEY.

From "Transactions of the Society of Engineers."

THERE was a time in the history of the arts and manufactures—and that time is well within the memory of the youngest member of the profession—when every department had what were termed its waste products. In some instances this waste was an unconscious one, unrealized by those whom it most affected. In others, however, manufacturers possessed a knowledge of their loss, but strove in vain to lessen or prevent it. Especially was this the case in metallurgical science, where, almost from the first, the value and usefulness of many waste products were fully recognized, and where continued efforts were made to utilize them. It is but a few years since that the gases of the blast furnace were truly yet regretfully looked upon as waste, but for which at length inventive talent found a profitable application. And so in other departments of manufacture, the rapid development of mechanical and chemical science has led to the successful application of waste substances in directions previously but little hoped for, if not wholly unthought of. And thus to-day finds some of the most simple of our industrial processes, each the parent of a variety of others, all more or less beautiful in their conception and happy in their practical results; all tending to promote and sustain commerce, and to enrich the nations of the world. Witness the ultimate results of the destructive distillation of coal, or the more recent perfect utilization of the hitherto valueless waste produced in the manufacture of spun silk. The term "waste products" is now all but expunged from the vocabulary of applied science, and that of "bye-products," so pregnant with meaning, has by common consent become its valued substitute. Manufacturers, instead of seeking how best to rid themselves of what they in their ignorance deemed a nuisance and an incumbrance, are now for the most part busied in devising methods for its careful retention, with the view to its ultimate conversion into substantial profit.

One of the most expensive, cumbersome, and until recent years, useless products in the metallurgy of iron is the slag of the blast furnace. The yield of this substance from the Cleveland blast furnaces is about half as much again as that of the iron produced, while its bulk is more than three times greater than that of the metal. In the hematite districts the proportions of slag and iron are about equal. This mass of material absorbs and radiates an enormous amount of waste heat, which is so much loss of power. Hence attempts have been made to utilize the heat thus wasted, but without success. It is a heavy incumbrance, inasmuch as large tracts of land have to be purchased whereon to deposit it, the investment being of course wholly unremunerative. One iron manufacturing firm at least within the author's knowledge is exempt from this tax upon its capital, and that is the Hudson Iron Works in the United States, where the slag is used to fill in shallow bays. Thus, instead of having to purchase land for the deposit of the slag, the latter is actually utilized for the formation of land. Again, it is a source of great inconvenience at the blast furnace, accumulating there as it does in a hot, viscous mass, difficult to handle, and requiring special tools for removal. In fact, the labor spent upon this unproductive substance often equals the whole productive labor of the blast furnace. No wonder, then, that from the first persistent efforts have been made either to utilize it or to get rid of it altogether. The variety of schemes proposed for either or both of these purposes has only been equalled by the ingenuity displayed in devising them.

The refractory character of blast-furnace slag pointed it out in very early times as a suitable material for road-making, and it was thus first used, being broken up by hand for the purpose. But the demand in this respect is comparatively limited, and falls so infinitely short of the supply, that our slag heaps

have gone on steadily increasing in bulk until at old-established works they have attained enormous proportions. In some Continental States, where stone is scarce, slag plays a prominent part in road-making, where it can be procured in large quantities. In Silesia, and other similarly situated countries, careful attention has been devoted to the treatment of slag, in order to render it as suitable as possible for road-making, being the only available material for that purpose. The great brittleness of slag is one of its objectionable features, so that in the first instance attempts were made to devitrify it. This implies a supply of cheap fuel, otherwise the process would prove too costly. As cheap fuel is scarce, devitrification is in some places successfully effected by allowing the slag to accumulate around the blast furnace, and to cool slowly under considerable pressure. This method is adopted at Tarnowitz and other districts in Silesia, where the slag accumulates to a thickness of 18 inches before removal. The process is, however, imperfect, only the lower half becoming devitrified; but it nevertheless furnishes a good road-making material.

Another direction in which attempts have been made to utilize slag is to adapt it for constructive purposes. In the Cleveland and some other districts the slag is run into moulds and afterwards used for foundations, embankments, reclaiming land from the sea, and for similar purposes. In the Black Country the author has seen walls, and even houses, built up of moulded slag blocks, and they have in some instances presented a very pleasing appearance, owing to the variegated nature of the slag, but in all these cases there is a limit to the appli cation, whilst there at present continues to be no limit to the supply of the material. Attempts have been made to utilize slag for ornamental purposes, by running it into moulds and afterwards annealing it; but the latter process was found to be too costly, and this anticipated source of relief proved to be but one of disappointment.

In some Continental countries building stone is very scarce, and as slag appeared to contain the elements of a good building material, it was submitted to seemingly endless experiment, attended by apparently endless failure. In time, however, success came, and the result was the production of a very useful material for certain kinds of construction. The process of manufacture as carried out at Königshütte, in Silesia, consists in running the slag from the furnace into a hemispherical basin on wheels. The bottom of this basin is covered with sand or fine coke dust to the depth of about 1¼ inch, and the wagon is drawn to the point where the bricks are to be made. The slag and sand are mixed together with a curved iron tool until most of the gases have escaped and the mass is about the consistency of dough. It is then drawn with the same tool into a mould with a hinged cover, and punctured several times to let out the gas. The cover, which fits into the mould, is then turned down, and the slag becomes compressed. By the time three or four moulds have been filled, the first slag brick is sufficiently solid to be removed. This is done by raising a clamp, which allows the mould to separate. The red-hot brick is now drawn into a kiln, covered over with powdered coal and left to anneal. Each kiln contains 1,000 bricks, and is from three to four days in cooling. Four men can make 500 of these bricks in three hours. The loss in the manufacture from breakage is about 20 per cent. These bricks are rough on their surfaces, but on account of their larger size do not require more mortar than an ordinary brick. They do not readily absorb moisture, and for that reason are extensively used in the construction of foundations. In Silesia, these bricks cost 25 per cent. less than an ordinary brick.

In the Hartz mountains the lead-furnace slags, which are silicates of iron, are run into moulds and compressed, thus forming bricks for building purposes. They are, however, of inferior quality, being very brittle, and houses built with them are usually quoted with compo. One of the first successful attempts on the Continent to transform slag into a useful building material was made by M. Sepulcre, a Belgian engineer. His process consists in running the slag into pits having the sides inclined at an angle of about 30 degrees. This quick increase in the sectional area of the pit allows the solid crust which forms on the top

of the slag to rise with it without becoming attached; the whole mass of slag is thus liquid, and solidifies from above and under pressure, being left several days to cool. When first turned out the stone thus produced can be readily broken into any required shape; but it gradually hardens on exposure to the atmosphere. The primary conditions of success with this process are that the furnace is in good working order, and that the slag contains about 40 per cent. of silica. If lime be present in excess, the stone will crumble to pieces on exposure. From experiments made by the "Conservatoire des Arts et Mètiers," in Paris, with the stone produced by M. Sepulcre's process, it was found that when made from the slag of grey iron it became fissured at a pressure of 3,100 lbs. per square inch, and was crushed under 5,700 lbs. Stone made from white iron showed fissures at 3,450 lbs., but it did not give way until a crushing strain of 12,600 lbs. per square inch had been reached.

Another application of blast-furnace slag on the Continent is that of glass manufacture. In Belgium, experiments in this direction proved so successful that it led to contracts being entered into, by the glass manufacturers in some parts of the country, with the proprietors of blast-furnaces for the regular supply of slag for this purpose. The only preparation necessary is to run the slag out on to iron plates and to cool it with water. By far the most general method of dealing with slag is to granulate it with the view of its ultimate adaptation to constructive purposes; and this course of treatment is carried out in various ways both in England and on the Continent. When in Belgium a short time since, the author visited, amongst other industrial establishments, the ironworks of M. Dallemagne, at Sclessin. There the slag is granulated in a very simple manner. On being run off from the blast furnace it is made to pass through a stream of water, which has a sufficient velocity to carry the grains of slag into a pit, from which it is raised and delivered into wagons by an endless chain with buckets attached. The water enters under the slag and the steam formed at the junction of the two is said to materially assist in breaking up the slag. The only labor required is that of a couple of boys, who occasionally agitate the mixture of slag and water, one at the point of entrance and the other near the buckets. The invention of this simple process of disintegrating slag, which is extensively used in Belgium and France, is said to be due to M. Minary, director of the Franche-Comté Iron Company. In these works, which consist of five blast furnaces, each producing 20 tons in twenty-four hours, the introduction of the system resulted in the saving of the wages of twenty men who were previously occupied in charging the slags, and of five blacksmiths who repaired their tools. The saving effected is from 5,000 to 6,000 francs per annum. Beyond this saving, however, there is another absolute gain afforded by the utilization of this granulated slag in various departments of the works. The first uses to which granulated slag was there put were as a substitute for gravel, and for making the bed of the casting-house. The pigs came out of these beds very clean and bright, and were preferred by the puddlers even to those cast in iron moulds. This method of using the slag is now of almost universal application in the Siegen district in Prussia, where most of the furnaces run on spiegel. The cleanness of the pigs cast in slag beds suggested its partial application to moulds for fine castings. The fine dust was sifted out from the granulated slag, and with it the moulds were sanded, the result being that the castings turned out better and cleaner than before. As may be supposed these applications only consumed a very small portion of the slag; the surplus was therefore offered to the railway companies, and they find good use for it as a ballast, paying a moderate price for it; the foundries thus obtained a revenue from what had previously been but a source of continual expense. It is stated to make a good ballast; being porous it retains but little moisture and packs very well.

From the first moment that the granulation of slag became an accomplished fact its substitution for sand in construction suggested itself, and its use in this respect has been attended with very good results. It was first mixed with lime and used as a mortar, and some having

been left from a job was soon afterwards found to have become very solid. This was suggestive of further applications—the preparation of concrete and the construction of foundation walls. To both of these purposes it has been successfully applied. Then followed the idea of manufacturing bricks, and the proprietors of the Georgs-Marienhütte, in Hanover, mix the granulated slag with lime, press and sun-dry the bricks moulded therefrom, and have used them very largely in the construction of their buildings. They cost much less than the ordinary bricks, and being almost white give a light, cheerful air to the buildings. Another application of granulated slag consists of coating the surfaces of unburnt bricks with it, and burning them out of contact with coal. This produces an enamelled face—an appearance which is much sought after in some places on the Continent. By the admixture of slag sand with fire clay the quality of the bricks made therefrom is said to be greatly improved. This suggests the application of the sand in the manufacture of bricks for puddling furnaces, where a highly refractory material is still a desideratum. The possibility of manufacturing cement from granulated slag has been demonstrated at one of the largest ironworks in Germany, where experiments were carried on for several years with the view of determining the point. Large works have been constructed in connection with this foundry, where an artificial cement is manufactured which is said to be equal to the best Portland cement, and which is produced at a very low price.

The important part which carbonic acid plays in rendering soluble the various mineral substances required by plants for their growth, has led to the supposition that blast-furnace slags can be profitably applied for agricultural purposes. Whether German ingenuity has succeeded in the successful application of slag in this respect the author is not aware. That English skill has not been able to effect the object he is aware, as will presently be shown. Hitherto the author has confined himself mainly to the theory and practice of Continental metallurgists in the matter of the utilization of the slag of blast furnaces. He will now proceed to deal with the practical development of the question in England, noticing *en passant* such proposals bearing on the subject as are of interest or value. In this, the home department, as it may be termed, the author is able to supply information of a more precise and detail character, and to show by diagrams and models the exact form of apparatus used in producing given results, which results, moreover, are themselves illustrated by samples of the various products.

Amongst the earliest scientific investigators of the question of applying furnace slag to economic purposes was Mr. Bessemer, one of our honorary members. In the year 1863, Mr. John Gjers, of Middlesborough, also a member of our Society, patented a plan for granulating slag by running it into agitated water. The sand thus produced was used in place of siliceous sand on the pig beds. Mr. Gjers, however, informs the author that he gave up the practice because in Middlesborough no cover is used over the pig beds, and in wet weather some trouble was occasioned by the slag absorbing and retaining water. Moreover, sand is very cheap in that part of the country, and the ironmasters there failed to appreciate the advantages of having a good flux on their pigs rather than a siliceous sand covering, which does not tend to promote good yield either in the puddling or the cupola furnace. With covered pig beds Mr. Gjers experienced very good results.

In 1871, Mr. David Joy submitted to the iron trade of Cleveland a plan for shipping slag in blocks, differing somewhat from a plan proposed by Mr. Charles Wood a year previously to the Tees Conservancy Commissioners, not only for taking the slag to their breakwater, but also for removing it direct from the furnace by an endless band. Simultaneously with this a similar plan was projected by Mr. Thomas Bell, and soon after practically worked at Walker. Messrs. Smeeton and Bowler, Mr. Lurrman, and Mr. Homer also deserve honorable mention for the active part each has taken in promoting the solution of the slag difficulty. But, perhaps, no names have been more prominently before the public of late years in connection with the subject than those of Mr. Charles Wood, of the Tees Ironworks, Middlesborough, and Messrs. Pcd-

mer, of the Spring Vale Brickworks, Hammersmith. Mr. Wood has designed and brought into successful operation machinery for the granulation and disintegration of slags, whilst Messrs. Bodmer, taking the results of Mr. Wood's process, have been no less successful in utilizing them for constructive purposes. Messrs. Bodmer have also devised a special method of reducing slags to a state of division of various degrees of fineness. Mr. Wood's disintegrators are of two kinds, horizontal and vertical; the former is used for reducing the slag coarsely, and the latter for producing a fine slag sand. It consists of a circular revolving table composed of thick slabs of iron. The table is kept cool by means of water which circulates through channels formed in the slabs. A set of scrapers are attached to a fixed arm carried above the table. The table is made to revolve very slowly and the liquid slag is delivered on to it, and forms its own thickness, varying from $\frac{1}{2}$ to $\frac{3}{4}$ inch. As soon as the slag has parted with sufficient heat to become solid, water is allowed to run freely upon the surface, and by the time it arrives at the scrapers it is sufficiently cool to part from the tables readily and break up. It then drops into the slag wagons, and as each wagon is filled it is removed and another takes its place.

The slag-sanding machine is the reverse in principle of that just described; in shape it somewhat resembles a rotary puddler. Its sides, however, are only made sufficiently high to enable it to contain from 2 feet 6 inches to 3 feet of water in the bottom. This cylinder is kept in motion by a small steam engine, and the water is agitated by means of buckets placed inside the periphery of the cylinder. These buckets are perforated so as to act as screens, to separate the sand from the water. They also elevate the sand to the top of the machine, where it drops into a spout, and is conducted thence into wagons. The speed of the machine is about 100 feet per minute, or about four and a half or five revolutions, according to the nature of the slag. Thus, the water is kept in a violent state of agitation, and the liquid slag, which is run into it direct from the furnace, is instantly scattered in the body of water in the form of sand, the water taking up the heat and throwing it off again in the shape of steam. The action of the machine is so perfect that no crust nor any large pieces are allowed to form. On the table are samples of this slag just as it comes out of the machine. The slag is delivered in a constant stream into railway trucks, in a suitable condition for being dealt with for manufacturing purposes.

The next point for consideration is the manner in which the material thus produced is converted into a commercial article. There are four chief purposes to which granulated slag is applied: these are the manufacture of bricks, mortar, concrete, and cement, and chief amongst those who have persistently devoted themselves to the question of utilizing slag in these respects are Messrs. Bodmer & Co., who take up the question exactly where Mr. Wood leaves it, and so carry out the ultimate application of the slag in practice. After proving his machines to be a success, Mr. Wood sent some of the slag sand to Messrs. Bodmer, who, by mixing eight parts of the granulated slag with one of cement, produced a valuable brick, specimens of which are on the table. By Bodmer's process the sand requires no further manipulation than the mixing it with lime, and submitting the compound to hydraulic pressure. After two or three weeks' exposure to the air the bricks are found to be fit for use. In making mortar Mr. Wood uses five parts of the sand to one of lime, which, when well ground up together, form an excellent mortar, nearly equal to cement. By adding about 5 per cent. of ironstone to the mass, Mr. Wood has found that the strength of the material is greatly increased. Concrete is made by combining six parts of the rough slag from the first machine with one part of the mortar just described. The materials are worked up well and moulded into blocks, which are found to be very suitable for foundations and for the walls of cottages. Concrete made from Mr. Wood's rough slag mixed with Portland cement has been extensively used in carrying out the drainage of Middlesborough; and, as far as the author is informed, its use has proved very satisfactory. The manufacture of cement from slag has also been attended with good results, as will presently be shown.

An important consideration in determining the commercial success of any invention, and one to which the practical mind intuitively turns at the outset, is that of cost. It is satisfactory to find that in the utilization of slag, for the purposes mentioned, the question of cheapness in production has been placed beyond doubt, as shown by the following statement of facts, which have been compiled from actual working, and communicated by Mr. Wood to the author:

SLAG SAND.

Taking the make of the furnace at 25 tons of iron, there would be a yield of about 36 tons of slag. To convert this into sand the expenses would be—

	s.	d.	
One man, per day	4	0	per shift.
8000 gals. (water) at 3*d.*	2	0	
Wear of machine	3	0	
	9	0	×12÷36=3*d.* per ton.

Concrete Blocks.

	s.	d.
Rough machine slag, 8 tons,	4	0
Slag mortar, 1 "	4	0
9 "	=8	0
Labor, 1*s.* per ton	9	0
	17	0 ÷9=1*s.* 11*d.*

1*s.* 11*d.* per ton, or ¾*d.* per cubic foot. If with ironstone, about 1*d.* per cubic foot.

Mortar from Slag Sand.

		s.	d.
5 tons sand, at 3*d.*		1	3
1 ton lime, at 15*s.*		15	0
6	16	3 ÷6=	2 8
Grinding		1	4
		4	0

Four shillings per ton.

Bricks

	s.	d.
2 tons 10 cwt. of slag sand a 3*d.* per ton	0	1½
Lime	4	0
Wear of machine	1	3
Coals and water	1	0
Labor, &c.	3	2
Per 1000	10	0

The following analysis of blast-furnace slag has also been furnished by Mr. Wood to the author:

ANALYSIS OF FURNACE SLAG.

Silica	38.25
Alumina	22.19
Lime	31.56
Magnesia	4.14
Protoxide of iron	1.09
Manganese	trace.
Calcic sulphide	2.95
	100.18

The author has already referred to the part taken by Messrs. Bodmer in converting the slag sand produced by Mr. Wood's machinery into bricks. But Messrs. Bodmer have done more than this; they have designed a system of slag reduction upon what may be termed the dry principle in contradistinction to that of Mr. Wood, which is on the wet principle. This system had been perfected after protracted experimental working at blast furnaces in Wales. A careful investigation into the properties of slag produced in the wet way led Messrs. Bodmer to the conclusion that there were conditions to which slag so treated was inapplicable. They found that sand obtained by running the slag into water consisted of large and small granules of a spongy porous character and very light. Carefully examined it would seem that the water causes the slag to form agglomerations of cellules, each of which encloses a certain amount of moisture. When heated the moisture becomes converted into steam, which does not escape, but recondenses upon the temperature being lowered. It is found to be practically impossible to dry such sand without previously pulverizing it. This spongy slag, when used as railway ballast, does not readily settle down into a solid compact mass, and hence arises an objection to it in this respect. It is, however, well adapted for certain descriptions of concrete and for brickmaking. How far its sponginess affects its resistance to compressive strain, the author is not prepared to state. In manufacturing bricks from spongy slag-sand, Messrs. Bodmer find it necessary to pulverize the sand before they are able to use it, in order that it may attain the requisite degree of dryness.

The object of Messrs. Bodmer therefore was to produce the sand in a dry condition, and they effect this end by passing the slag through rolls. The slag

is delivered direct from the blast furnace into a pair of rolls, revolving either with equal or differential surface speeds. If the object is simply to obtain the slag in a convenient form for removal, the rolls are set wide apart; with rolls working at equal surface speeds the slag is delivered in the form of a continuous band of the same width as the rolls and about ¼ inch thick. The slag is either deposited in a truck direct from the rolls or fed upon a forwarding apparatus, as most convenient. With plain rolls moving at differential surface speeds, or with corrugated rolls, the slag is delivered in slabs. Slag produced in this manner, and without being brought into contact with water, retains its crystalline fracture and hardness, as will be seen by the specimens on the table. This condition is most favorable to its use for ballasting and for the manufacture of concrete. If the slag is required for the manufacture of bricks, mortar, or cement, plain rolls revolving at differential speeds are employed, the rolls being set a greater or less distance apart, according to the thickness of slag scale desired. When the slag on issuing from the rolls is allowed to drop into water, it is rendered amorphous without becoming spongy, and without the capacity for retaining water peculiar to spongy slag. Such slag being very friable, as the specimens on the table show, can be further disintegrated, if desired, with facility. With the rolls placed very close together and with considerable differential speeds a very fine thin scale is produced, especially suitable for the manufacture of slag cement.

In carrying out their process of disintegration Messrs. Bodmer do not employ any special mechanical arrangement. The rolls are of the ordinary type, about 25 inches in diameter and 20 inches in length. Beneath them is a moving shoot by which the rolled slag is fed either on to a chain belt or a bucket belt, which delivers the slag into the trucks. A pair of rolls of the dimension stated will take through about 94 cubic inches of slag ¼ inch thick per revolution, or working at a speed of thirty revolutions per minute, and the slag weighing 120 lbs. per cubic foot, 195 lbs. per minute, or more than five tons per hour. This rate of working is found ample to meet the exigencies of the greatest rush of slag. Messrs. Bodmer's method of preparing the slag has not yet been adopted in practice, but the author is informed that a license to work their patents in the Middlesborough district has been granted by the inventors to a company which has been formed in the iron districts for the utilization of furnace slag. The same company has also arranged to work Mr. Wood's patent.

In converting the slag into bricks, Messrs. Bodmer first feed that material into a hopper placed over the measuring apparatus, from which it issues in a uniform layer on a carrier belt. At the same time the lime and other cementing materials are each fed into a separate hopper and measuring apparatus, and upon issuing therefrom are passed together through a mixing apparatus, from which the mixture falls upon the traveling layer of slag sand. The cementing material and the sand are then passed in combination through another mixer, in which they are intimately incorporated. The compound is then delivered on to a traveling belt, by which it is conducted to the brick press. The whole of these operations, with the exception of the feeding of the hoppers, are automatically performed. The brick press is on the hydraulic principle, and is worked by a hydraulic force pump and an accumulator. It consists of a circular table revolving horizontally, and fitted with six pairs of moulds. Whilst four moulds are being filled, four others are under pressure, and finished bricks are being discharged from the remaining four, the processes being carried on simultaneously. The bricks are removed on barrows to the drying sheds, where they remain until ready for use. The time required for ripening is from three to five weeks, according to the character of the lime used, and according also to the weather. The press is worked at the rate of seven strokes per minute, producing therefore twenty-eight bricks per minute, or at the rate of 80,000 per week. For this production two men and four boys are required, exclusive of wheelers and pilers.

A series of experiments were made for ascertaining the degree of absorption possessed by bricks of various kinds. The bricks were dried on a heated iron

plate and were then weighed. After having been immersed in water for fifty hours, they were again weighed, with the following results:

	Best Gault Clay Brick.	Best Stock Clay Brick.	Bodmer & Co.'s Bricks.		
			Sand and Lime.	Blast Furnace.	Slag and Lime.
				Dry slag.	Spongy slag.
	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.
Weighed dry	5 15	4 13	6 9$\frac{3}{4}$	7 7$\frac{1}{2}$	5 7$\frac{1}{2}$
Weighed wet	7 2$\frac{1}{4}$	5 14$\frac{1}{2}$	7 1$\frac{1}{4}$	7 12$\frac{1}{2}$	5 14$\frac{1}{2}$
Water taken up per brick	1 3$\frac{1}{4}$	1 1$\frac{1}{2}$	0 7$\frac{1}{2}$	0 4$\frac{3}{4}$	0 6$\frac{3}{4}$
Percentage of water taken up	20.26	22.72	7.09	3.97	7.69

The manufacture of cement from slag presents several features which are worthy of consideration. A great similarity exists between trass, a cementitious substance found along the banks of the Rhine, puzzolano, and blast-furnace slag, as will presently be seen by the results of analyses. Notwithstanding this similarity it does not appear that furnace slag has yet come into commercial use as a cementing material. It has, however, been made both in England and on the Continent, and has been successfully used by those by whom it has been made. But as far as the author can ascertain it has not yet become a regularly constituted article of commerce in any country. The reason for this appears to lie in the fact that unless the slag is disintegrated under pressure and out of contact with water the material is not in a proper condition for the purpose. Messrs. Bodmer therefore pass the slag through rolls closely spaced, and to produce a reliable cement from it they grind it to an impalpable powder in company with the lime. The slag must be perfectly dry and at the same time friable. The stronger the hydraulic properties of the lime used, the more reliable the slag cement becomes. Practice has, moreover, proved that the slag from a grey iron furnace yields the best results.

The following table gives the results of some comparative experiments with slag and Portland cements:

Figures taken from Experiments made on the Strength of Portland Cement by John Grant.			Experiments made with Slag Cement by Mr. J. J. Bodmer.		
Weight of Cement per Bushels in lbs	Age after Ganging.	Tensile Strain per square inch in lbs.	One part Lime and seven parts Slag by weight.	Age after Ganging.	Tensile Strain in lbs. per square inch.
106.7	7 days	157.6	....	....	....
107.6	"	156.56	....	....	....
111.75	"	201.63	....	....	....
114.15	"	269.78	....	14 days	271.22
119.04	"	248.03	....	....	....
119.07	"	305.89	....	....	....
121.0	"	409.77	....	....	....
"	14	472.26	....	1 month	470.18
"	28	499.51	....	....	....
"	2 months	523.44	....	....	....
"	3 "	558.62	....	....	....

The results were obtained under tensile strains, and the slag cement was composed of six parts of slag from a blast furnace producing No. 3 foundry iron, and one part of lime of medium hydraulic properties.

The following table gives comparative analyses of slag cement, trass, and puzzolano, and shows the similarity already referred to as existing between those substances:

	Blast-Furnace Slag.					Trass.	Puzzolano.
	Cleveland District.			Wales.			
Silica	36.2	40.75	34.0	49.50	45.0	57.	44.50
Alumina	26.	24.47	24.33	15.20	16.42	12.	15.
Lime	27.	24.50	34.0	19.70	26.78	2.60	8.80
Magnesia	9.	7.17	5.88	3.0	0.40	1.	4.70
Protoxide of iron	1.30	2.05	0.07	8.82	5.20	5.	12.
Potash	.....	.....	.....	.....	0.46	7.	1 40
Soda	.....	.. .	.....	.....	.....	1.	4.
Sulphur	0.4	0.65	1.72	1.29	.....	.....	.....
Water	.....	.....	.....	.....	.....	9.40	9.20
Protoxide Magnesia	.....	.....	.. .	.....	5.64	.....	.....

The applicability of slag to agricultural purposes, to which reference has already been briefly made, is at present very problematical. Although it contains ingredients which in themselves are fertilizers, it is questionable whether these substances exist in the proper form for assimilating with the soil. The lime in the lag, for instance, assumes the form of a silicate, a totally different condition from that in which it is used in agriculture. Mr. I. Lothian Bell, the President of the Iron and Steel Institute, himself a producer of blast-furnace slag to the extent of about 1,000 tons per day, informed the author that, being desirous of utilizing the slag, he granulated some and applied it on land where it was somewhat heavy. On comparing the crops on the land thus treated with those on similar adjoining land not dressed with slag, he could detect no difference whatever. It would, therefore, appear, that as far as this application is concerned, the conditions under which it may be effectively used have yet to be determined.

Another application, which, although it has proved to be more successful than the last, is at present quite as far from being adopted in practice, is that of a clothing for steam pipes. To produce the slag in a proper condition for this singular purpose, a blast of steam, water, or air is forced into the stream of viscous slag as it is run from the furnace. Thus treated the slag assumes a fibrous form similar to spun glass, and is known as "furnace wool." When the stream of slag is imperfectly acted on by the current directed against it small globules are formed about the size of shot. This fibrous slag is a bad conductor of heat, and has been used as a covering for steam boilers and pipes. Slag has also been used for adulterating emery powder.

Such, then, are the principles and practice of slag utilization, as they exist at the present time. The principles can hardly be said to be fully developed, nor the practice much more than in its infancy. Further investigation, for which their is room, will probably be found to modify present principles, whilst extended working will doubtless suggest alterations in practice, and both will add to the discovery of more numerous uses for slag. The author is convinced that these three things will result in time, s a natural consequence of the general desire to promote the economic use of blast-furnace slag, and thus to convert a source of absolute loss into a means of permanent profit. And what is true as regards the utilization of slag holds good also with respect to other substances which may now be treated as waste. Doubtless the progress of science, in promoting economy of working, will yet lead to the utilization of substances for which at present no satisfactory use can be found. All matter was but so much waste before the creative faculty of man provided appliances for its util zation. And so human progress will further show, that what is now the veriest waste, will, in the course of time, assume a condition of value. Thus will art be made to approximate to nature, in that she will know no waste.

In 1874 France produced 1,360,000 tons of pig (crude) iron, 760,000 tons of wrought iron, and 155,500 tons of steel.

The total length of tramways laid down in Vienna is about five geographical miles, and the service is conducted with 554 tramway cars and 1,864 horses. Ten per cent. is the dividend on the paid-up capital.

TOWN SURVEY OF KINGS COUNTY.*

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

A GLANCE at the chart of New York Bay and Harbor shows the City of New York, a county in itself, dropping down from the main land of Westchester County towards the bay, in the form of an elephant's trunk, with the Battery as its prehensile point. On the west side it is separated from New Jersey by the stately Hudson River, and on the east from Long Island by the East River, which is in great measure one of the mouths of the Hudson, emptying into Long Island Sound.

This form of the great city is significant, for the elephant to which it belongs, commercially, is not Westchester County, nor New York State, but a vast group of counties and States reaching westward to the Pacific Ocean, which draw through this trunk the products of the world beyond the sea, and in turn deliver up their wealth of production in New York Bay.

As a natural result of the commercial supremacy of this city and its noble harbor, its growth, with that of its environs, has been rapid and regular. At the last census (1870) New York numbered 942,292, Brooklyn 396,099, and Jersey City 82,546; whereas, in 1850, their respective population was 515,547, 96,838, and 6,856. But this does not represent the legitimate population of New York, since the facilities for suburban life have been so multiplied, to keep pace with the city development, that it is simply the main business center of a radius of thirty or forty miles, chiefly built up by its direct or reflex action, and aggregating millions of people dependent on its welfare.

There are several local causes for the growth of the suburbs of New York in keeping with, or in preference to that of the city proper. The city promontory or trunk is long and narrow in form, while its facilities for commercial work chiefly concentrate at the more southern and older part; the lower end therefore filled up gradually until the district below 23d street ceased to show increase at different census takings, and the upper city became the place of development. But this proved a very expensive place to develop, from the rocky and irregular nature of its formation, from the loss of area taken by the Central Park, and the contingent increase in property values. The question of time and comfort in transit came into play also, and the locomotive, with its swift and comfortable trains, gave to the cheaper areas of construction, and the charm of villa life, a powerful rivalry with the tedious stages and horse cars of the city proper, the excessive rents, and other living expenses. It is estimated that it has cost not less than $500,000,000 to put the streets and building lots of upper New York, such as they now are, into condition for use; and unimproved city lots six to eight miles north of the City Hall are worth the price of a comfortable suburban residence. This explains what the census of 1870 shows, that within a radius of forty miles New York contains 41¾ per cent., New Jersey 24¾, Brooklyn 17 and its suburbs 6¼, Westchester 6, and Staten Island 1½ per cent. of the aggregate population concentrated around New York Bay.

The immediate relation of this surburban life to New York City is singularly illustrated by the annual statistics of railway movement. In 1873, of about 37,000,000 passengers carried to and from the city, about 20,500,000 were by the New Jersey roads, 13,500,000 by the New York Central, Harlem & New Haven roads, and 3,000,000 by the Long Island roads. Of these the average receipt per passenger was, for the westerly lines 55 cents, the northerly 81 cents, and the Long Island 34 cents, showing an average travel for all directions of less than thirty miles. A result like this is significant to railway engineers and owners of suburban lands. It shows that the three great cities on the Bay represent little more than one-half the interested population, of which about 60,000

* Report of Samuel McElroy, C. E., Superintendent of Survey, submitted Oct. 31, 1874.

are in daily transit to and from New York. It also shows an annual exodus and growth, due to the rapid increase of the great center, equivalent to about 47,500 persons a year in the suburbs, on the average of twenty years past, an average which must be largely multiplied to give the actual exodus and growth of 1873 or 1874.

If we turn from this glance at the increase on New York Bay and vicinity to rapid survey of the suburbs themselves, around the three prominent cities, we see that New Jersey far surpasses the others in growth, although Newark Bay and the extensive marshes of the Hackensack and Passaic Rivers practically force expansion to more westerly districts; Westchester being rough and rocky, as is Staten Island, and both better fitted for summer than winter life. If we examine that large section of Kings County which lies on the easterly side of the Bay, with an average distance of about seven miles from the Battery, we find a country singularly favored in its natural characteristics. With a picturesque and commanding front on the Bay and Harbor, and direct communication with ocean commerce; with soil whose fertility is a proverb; with broad and easy slopes delivering towards the bays on the south and east, admirably adapted to street and house construction; with an abundant supply of the purest and softest water; with fine roads, attractive boating, bathing, fishing and hunting; with a population intelligent, industrious, frugal, long associated with the land, and generally affluent; in the whole radius of forty miles we have named, this area, which represents about $15\frac{1}{3}$ per cent. in size, cannot be surpassed in advantages for suburban residence. Nevertheless, while within twenty years the other suburbs of New York have accumulated a population of not less than 870,000, which should give this section 133,000 increase, and still more from its proximity to the Bay; the actual increase from 1850 to 1870 is but 16,300 on about $41\frac{3}{4}$ square miles of unexceptional territory. If New York City is the active elephant's trunk which ministers to a whole nation, these five towns of Kings County lay comparatively supinely on the Bay and Harbor in the form of a huge turtle, with Red Hook Point for one claw, Coney Island Point for the other, and the Bay Ridge bluffs for its massive head.

There is a reason for this, and a very simple one. Through this whole area there is no direct steam railway communication with New York; no way in which, with regularity, frequency, comfort and speed. a business man can be carried to and from the city, as he can be carried in any other direction; and in consequence of this an acre of building lots in the rocks or swamps of Harlem, six or seven miles from the Battery, is worth twenty-five times as much to-day as an acre in Kings County no further away!

Of course the people of this district have been more or less touched by the spirit of the age. Various contiguous improvements in Brooklyn have made rapid increase in values near them, and brought increased population. Operators from Brooklyn or New York have here and there purchased farms for investment, and united with the farmers in urging local improvements. Several years ago, so many local plans of streets had been proposed, without any uniformity of interest, each owner cutting up his property as it suited him, and the necessity for organized development was so generally felt, that a Commission was appointed from the supervisors of the town, with the chairman of the Board of Supervisors, to lay out a general plan of streets, basins and bulkhead lines, over the entire area, all private plans being superseded by their authority. This Town Survey Commission of Kings County has now completed its work and filed its maps in the office of the Secretary of State and the County Register, with special maps in the office of each Town Clerk.

The general importance and magnitude of the work of this commission may be gathered upon the statement that about 2,289 miles of streets have been established, enclosing about 6,021 blocks, 320,760 building lots, with a possible population, at 7 persons per lot, of 2,244,900. In connection with this work, the bulkhead lines have been defined from the Brooklyn city line on the Bay to Fresh Creek Basin on Jamaica Bay, with plans of commercial basins adapted

to the most economical methods of construction and safest wharfage; a ship canal is located from Gravesend to Sheepshead Bay; and eight interior basins are laid out, on lands now worthless as marshes, for future commercial uses, and to facilitate building improvements. The total cost of this work for four of the towns, covering 36⅞ square miles, including maps of the fifth, was $73,119. The work of locating the street lines by monuments was done in 1871–2–3, the number set being about 2,800.

The immediate effect of this survey was to determine definite and systematic street plans, independent of local convenience. The district was studied carefully as to its present and future lines of development and movement, so as to obviate expensive future corrections. Respect was paid to established centers of population, but without destroying the harmony of the general plan which enveloped them. On this subject the following statement is made:

LINES OF MOVEMENT AND SYSTEMS.

A study of the experience of any old and populous city shows the great importance of placing the streets and avenues so that the blocks will range in lines parallel with those of greatest travel, and proper care in this respect is of great consequence to this portion of Kings County, which is certainly destined, in time, to contain a vast population.

The City of New York was treated by Jno. Randall, Jr., C.E., in the general plan made by him, as a commercial city, with its chief movements from river to river; but experience has not confirmed this theory, and the system of blocks is reversed from what it should be, for up and down town travel. As the streets lie across the lines of movement, there is great inconvenience from the limited number of channels, and from the continued interruption of those which do exist, at short intervals, by the street crossings, and New York now has crowded avenues, and expensive projects for increased facilities in northerly and southerly travel.

Want of forethought in this matter is a fruitful source of expense in street widenings and openings, and the tendency of prominent centers to connect themselves by straight lines, often diagonal to intervening systems, is well understood in city experience. In the earlier days of city life, lines may be considered radical in size or direction, which prove, in time, wise preventives to legislation and costly rearrangement.

It is also to be observed, that in the vicinity of a great commercial city like New York, water fronts become valuable for business, for landings, ferries, and otherwise, and where it can conveniently be done, there is an advantage in making the street system deliver towards them.

* * * * *

While the New Utrecht system adopts that of South Brooklyn, in carrying the streets easterly and westerly, to and from the Harbor, in the other towns the general system carries the streets from the vicinity of the City of Brooklyn to the ocean, or its bays, in a northerly and southerly direction. Under this theory of future travel for this district, a street was located from a point near Greenwood Cemetery to the Atlantic, which became the directrix for the streets easterly, and was called West streets, its line being parallel with the Ocean Parkway and the central part of Coney Island Avenue. A part of Gravesend is laid out west of West street with similar plan of streets, crossing Coney Island to the Atlantic.

In Flatlands this plan is modified on the necks, to adapt the streets to their natural drainage lines and water fronts. To accommodate this arrangement, Flatlands avenue was located from Avenue P at a point near the Gravesend Town Line to the New Lots line, the streets being established, as a rule, at right angles to it, as far east as Fresh Creek Valley.

"With some local exceptions controlled by existing improvements, a study of the plans adopted for these towns will show a broad, comprehensive and uniform system of streets running towards the ocean or the harbor, carefully connected with the city streets and avenues, and located without regard to farm lines or individual interests, so as to meet and develop the interest of the dense population destined in time to occupy this area; an area with which no

other, within the same distance from New York, can be compared in advantages for suburban life."

The question of street and block dimensions is important, and in this case was carefully considered. As a rule, the width of blocks is 200 feet, provision being made in certain cases for a width of 250 feet, intending to appropriate the central 50 feet for future rapid transit. The minimum and common width of streets is 60 feet, avenues 80 feet, with occasional widths of 100 feet. Parkways are occasionally provided 120 to 130 feet wide, and arranged for two carriage ways of 30 to 35 feet each, with a central promenade of 24 feet. The length of blocks is 700 to 800 feet. Under the authority given, the streets have ten per cent. of width of each side appropriated to court yards.

The method of measurement adopted for this survey was in some respects novel and of professional interest. After discussing the objections which obtain against surface measurement for accurate work, and are avoided by triangulations, and the delicate character of the coast survey base-lines, and the methods adopted by other engineers for similar work, the superintendent says:

"In this case, however, the distances for each block, and system of blocks, had to be actually determined on the ground, over this whole area of $36\frac{3}{5}$ square miles, involving a proximate length of street lines of nearly 2,000 miles; and it had to be done rapidly, with assistants under restricted pay, and in the simplest manner possible, with the ordinary field instruments, the Commission not feeling authorized to provide those of a higher class, or of any class.

* * * * *

"The attempt, in the varying changes of the day, to determine the temperature of a metal bar, laid on the ground, with a thermometer disconnected from it, as to accuracy of register for the bar, and multiplicity of notes and calculations, I wished to avoid; I also wished to obviate the multiplicity of level sights and corrections, and their chances of error; and also, the multiplied transfer stakes, for 50 feet lengths. Knowing that soft, clear, seasoned pine was much less affected by change of temperature, than any metal, easy to construct, transport, and handle, I concluded to make a trial of it for our bases.

"On this theory I arranged an apparatus consisting of a tripod about 7 feet long, carrying on a convenient drum about 600 feet of No. 13 annealed steel wire, and fitted with stay chains and a stout iron pin, to be driven in the ground and keep the tripod in place, when in use; also, a back stay rod, of the same length, driven in the ground, on line, supported by side stay chains and pins; between these the wire was stretched and supported at intervals of about 75 feet by ordinary wooden flags, fitted with sliding rests and keys, so that when the wire was secured behind the back stay pin, to a pin firmly driven in the ground, it could readily be brought to a level; or if the ground did not so permit, to a uniform inclination, for a distance of 500 feet or more, over the sliding rests of the back stay rod and the flags, and certain intermediate rests on the back led of the tripod. With a little practice this operation was rapidly and accurately made, the several flags, rod, etc., being first put in line on the main base, so that the wire near the back stay was plumbed from a plumb-clamp over the stake and tack, which was the starting (or intermediate) point of measurement. The wire being in line, under a tension of about 300 pounds, a pine rod $12\frac{1}{2}$ feet long, by standard, with brass butts carefully faced, was held under the wire with one end in contact with the face of the plumb-clamp, and a brass clamp properly faced and sliding on the wire, was put in contact with the other end and fastened by a hand-screw. A second sliding clamp was then put in contact with first and fastened, the rod being relieved. This clamp then formed the starting point for another measurement of the rod on the wire, being relieved and brought up to the forward clamp and reset as the measurement progressed.

"We had then an apparatus light, simple, easily transported, not easily injured, which three assistants could work in the field; a common spirit level sufficed for the wire in most cases, and in others the notes were so taken that levels on the several stakes gave data for corrections. The bases therefore did not require highly educated men, and the as-

sistants were relieved from multiplied notes and calculations. Test benches of 500 feet were established, and the rod, in this way, frequently tested, and particularly after a wet interval, as it was soon ascertained that moisture was by far the chief source of any expansion.

"In the more delicate processes of the Coast Survey, etc., temperature sometimes becomes a limit to work; in one scientific description 100° is made the limit; but our work had to go on in the hottest and sometimes in the coldest weather. Under these conditions, I consider this system of measurement the key to the successful completion of our work in time, cost, and correctness.

"The same rods were used from July, 1871, throughout the field work. Theoretically, the effect of changes in temperature, taking the modulous of steel, as adopted by the Coast Survey, at 0′.0000064 for 1° Faht., and of pine (or deal) by Joul, at 0′.0000023, would be on 100° range for 5,000 feet 3.20 feet in one case, and 1.15 feet in the other; practically, we found the changes of the rods slight, as a rule, in different seasons. For instance, Rod No. 1, on 500 feet test, January 9th to 31st, 1872, stood 0′.022 short (for whole distance); February 7th, 0′.0165; April 12th, 0′.023 long; May 8th, 0′.029 long. Rod No. 2, in August, September and October, 1873, ranged from 0′.010 to 0′.020 long on various intermediate tests. In July, 1871, a moisture test showed an expansion for a wet rod of 0′.500 in 5,000 feet; but as no measurements were made with a wet rod, our chief care was to detect the effects of absorption, which rapidly dried out.

"In New Utrecht, 60th Street was located parallel with 58th Street, and made the base of the adopted system, and 86th Street was established parallel with it, by measurements on 9th and 22d Avenues, this parallelogram being the basis of included or extended bases from West Street to 4th Avenue. In making the check measurement down 14th Avenue base, from 60th to 86th, the error was 0′.04, on a distance of 6,940 feet; and the diagonal base measured down 4th Avenue, also checked and proved the transit line. On part of the Ocean Avenue base line, a check measurement over a distance of 12,410 feet, by standard, came out 12,409.90. On all the main parallelograms, the measurements and transit checks were satisfactory, except in one case in Flatbush, which occurred through checks improperly reported, but was not deemed of sufficient consequence to alter, after the monuments were set, and is corrected on the maps, for main angles.

"In transit work, by using glass diaphragms in the instrument for intersection, which are much less subject to temperature and moisture changes than spider-lines or platina wire, and by care in multiplying or reversing sights, the work, in the hands of skillful assistants, proved very satisfactory, under severe tests, though carried on through all seasons, and with ordinary engineer transits."

As a practical comment on the value of this survey, it may be said that during its progress about 50 miles of streets and avenues have been completed, or are now in progress within the towns. Very favorable progress has also been made in the preliminary work of a steam railway intersecting them all, and running from a ferry landing at Bay Ridge, from New York, to a junction with the Canarsie, Long Island, and other railroads in Queens County. Other projects are also under discussion to provide for the large annual surplus of New York a cheap and convenient suburban development in this section; and it is hoped that the next ten years of its history will show a progress more in keeping with the results in every other direction from the great city.

It is announced that a very rich bed of nickel has been recently discovered in the forest of Glorud, in Norway. The ore proves to contain 3.59 per cent. of pure metal; an exceptionally large proportion.

Some experiments are being made in France on some iron ore which has been brought from Algeria. It is said that steel can be produced from this which is superior to any other for the manufacture of cannon.

IMPROVEMENTS IN BLAST FURNACES—THE CLOSED HEARTH SYSTEM.

From the "London Mining Journal."

THE closed hearth invented by Mr. Lürmann, and referred to in the *Mining Journal* some time since, appears to have given great satisfaction wherever it has been applied. It is well known that as a rule, a much larger proportion of slag than iron is produced; it is, therefore, a necessity for the metallurgist to get rid of the slag till a sufficient quantity of iron has been gathered at the bottom to have it tapped, which is generally done at certain intervals—say every 12 hours. To effect this discharge of the slag, it has been usual to construct the hearth with a so-called open forepart. This consists in the widening of the hearth in the front from 4 to 5 ft. in length, 2 to 3 ft. in width, and 2 to 3 ft. in height, being closed in the front by the dam. The lowest part of the top of this opening, protected by a tymp-plate, is generally 10 to 18 in. below the level of the top of the dam. The slag, to leave the furnace, has to travel underneath the tymp along the forepart over the dam, so that either it has to stand at a higher level in the hearth than the top of the dam, or—this is usually the case—the pressure of the blast effects the discharge of the slag.

This system was long acknowledged to have many disadvantages, and it was long felt that if the open forepart could be done away with they would disappear; in fact, the first blast-furnaces were without forepart, and have been and are known in Germany and Austria under the name of "Blauöfen." The hearth is made circular, and has a tapping-hole, two tuyeres, and a slagging-hole, consisting of a slit in the wall stopped with clay. When the slag has to be run off a hole is made in the clay of this slit, through which the periodical, not continuous, discharge takes place. A more primitive method, still in use in Styria, is to run off the slag, together with the iron, through the tapping-hole. This simple procedure, however, is only possible where the ore is very rich, easily fusible, and where the fuel consists of charcoal, where consequently but little slag is produced. These furnaces work with closed hearths. The labor at such furnaces being minimised, it has often been tried to adopt this system to coke blast-furnaces, but for a long time without avail. The slag of such furnaces is hotter, and dissolves the clay. When, therefore, the Blauöfen system was tried at the coke blast-furnaces, the hole in the clay through which the slag ran though originally small became soon larger and larger, much blast was lost and the fuel thrown through the so created opening. To stop the hole the blast had to be taken off, which occurred, however, so often that the ordinary plan was found to be more profitable. Still, eminent metallurgists—among others Prof. Tunner, of Vienna—considered the open forepart system imperfect, and strongly desired and advocated the adaptation of the closed hearth system to coke blast-furnaces. Mr. Lürmann when he found that slag would run through a block cooled by water had discovered the means to do away with the forepart. He applied his plan to a furnace in blast, and obtained results so good that all the furnaces at Georgs Marien Hütte, near Osnabrück, where he was then managing director, were altered accordingly. His system was soon adopted at most of the best ironworks in Germany, and later in the United States of America. It was also introduced in Austria, Belgium, France, and England; and he has since done much toward perfecting his invention. The hearth is entirely circular, there is no tymp, forepart, or dam. The blast tuyeres are 42 in. or more above the bottom of the hearth, and equally distributed all round. Between two of the tuyere-houses there is an opening for the slag discharge 32 in. high and 20 in. wide, covered in by cast-iron plates. In this opening a water-cooled casting is placed, of which the back part is flush with the inner side of the furnace. This

casting is smaller than the opening, to facilitate an exchange; the space left between the casting and the wall is filled with fire-clay and fire-bricks. Into this casting the scoria block is fixed, which is a block of metal, cooled by water, with a hole for the slag to run through. It may be made of any metal, cast or wrought iron, but preferably of bronze. The bronze scoria blocks last much longer than the cast or wrought iron ones, and need not, therefore, be exchanged so often. They are also cheaper in the end, as old cast or wrought iron scoria blocks are nearly valueless, whilst those of bronze fetch more than half their original price. The scoria blocks have wrought-iron pipes of 1 in. bore screwed into them for the inlet and outlet of water. The slag-hole has from 1 to 1½ in. in diameter; the size depends entirely on the quantity and consistency of the slag produced. It should be so chosen that as much slag is discharged as is made. The centre of the whole is from 12 to 16 in. below that of the tuyeres; the blast will, therefore, not be obstructed by the slag. The block is held in its position by a key to the casting; if the block has to be exchanged the key is taken out, and a bar with a nose put through the reserve opening. The scoria block, against the back of which the nose of the bar is made to rest, is then easily pulled out. The tapping-hole is placed wherever most convenient in the circumference of the hearth, the slag and iron need not, therefore, be run off on the same side, as is necessary at furnace with open foreparts.

In working furnaces on this system. It is not necessary when about to tap to stop the scoria-hole, as the slag will cease flowing as soon as the iron runs out of the tapping-hole. When the cast is completed, the tapping-hole has to be closed in the usual way; this is the only time when the blast must be taken off, except in case of accidents. At the same time the scoria block is cleansed from the scoria crust, then stopped first with sand, and afterwards with a little clay. These operations will be finished in three or four minutes; the blast is now turned on full. To prevent a thick crust forming behind the scoria block, only very little water should now run through it. As soon as the slag is observed at the tuyeres, the hole of the block has to be opened, which may be done with a wire rod, if the furnace work well, otherwise a blunt bar, a little less in diameter than the hole, must be driven through it some distance into the hearth, and then quickly pulled back. The slag will follow in a stream of the size of the hole.

As soon as the slag begins to run through the block the water must be so far turned on as to leave the block lukewarm. If the proper size of the hole of the scoria block, according to the quantity and quality of slag produced has been chosen, the slag will run interruptedly till next tapping time. For a large coke blast-furnace, with good hot thin slag, a hole of 1¼ in. has been found sufficient. Should blast blow through the hole continuously it is a sign that it is too large, and a block with a smaller hole should be put in. If temporarily less slag is made it suffices to put a bar tipped in clay into the hole, when this slag will cease to run. As soon as there is sufficient on again the bar is withdrawn. It is best to tap after a certain number of charges have been put into the furnace; the number is regulated by the quantity of slag run out through the tapping-hole at the casting time. For it is evident that this slag occupied the space between the scoria outlet and the top of fluid iron; it should be about 10 cubic feet, to prevent the iron from touching the scoria block. If, now, the above quantity be more or less than the 10 cubic feet, the number of charges should be altered accordingly. In case the furnace should work badly, the slag will generally run through the block easily, as one end of the latter extends into the hearth, whilst the slag would not do so had it to travel the long distance underneath the tymp along over the forepart over the dam. Should the furnace work so badly that the slag will not run even through the hole of the scoria block, the reserve opening must be used. The slag will always freely run through this opening which is considerably larger than the hole of the block. After a bogieful or two have run through this opening the crust behind the hole, which blocked the discharge of the slag through the scoria block, will have melted away. The opening may

then be stopped, and the scoria block hole opened.

It has been said to be a great disadvantage of this system that if the furnace works so badly that the hearth grows up there would be no means to work with bars inside the hearth; but the simple answer to this is that the bar working in such cases is of little avail, and that the proper remedy would be to alter the burdens. The closed hearth gives a better chance for the furnace to come round again than the open forepart system, as the heat is better kept together.

THE VENTILATION OF THE CHANNEL TUNNEL.

From the "Engineer."

WHILE we hold that the construction of a railway tunnel between England and France by private enterprise would prove a disastrous speculation for the original shareholders, we are by no means supposed to deprecate the carrying out of the work by the Governments of France and England, or, which comes to nearly the same thing, by public companies to whom a certain interest—say, four per cent.—would be guaranteed by the two nations. We shall not stop to consider the precise nature of the results which would accrue from the formation of the tunnel. It will suffice for the present if we admit that there is no reason why it should not be made under the conditions which we have laid down; and if we admit that the work may be carried out, the details of its construction and operation become legitimate subjects for discussion in these pages. The details of construction will probably be elaborated only as the boring proceeds; and it is also probable that they will not differ much from those of the St. Gotthard Tunnel. We shall have perforators propelled by compressed air, and rails to carry the *débris* to each end. Furthermore, the tunnel will be either double or single, and lined with brick in cement from end to end. Two lines of rails will be laid. Less would not suffice, and it is improbable that more will be attempted. We shall have then a tunnel which will be at least twenty miles long from end to end, without counting land lengths of tunnel on the coasts of England and France. This tunnel will fall towards the middle and rise towards each end, and so far as tractive power for the propulsion of trains is concerned, it may be regarded as a dead level, the inclines compensating each other. Up to this point there is hardly any difference of opinion about the structure. Most if not all engineers will agree that we have sketched roughly but accurately the future road under the Straits of Dover. But arrived at this point, chaos presents itself. No one has expressed a well considered opinion in public as to how the trains are to be propelled, or the ventilation of the tunnel is to be effected. So far as we can see the general expression of sentiment on the subject is: "Let us have the tunnel, and we shall easily work it and ventilate it." Now it appears to us that the ventilation of a tunnel twenty miles from air shaft to air shaft, and placed deep down below the sea, is a matter which cannot thus lightly be disposed off; on the contrary, the problem is one of unexampled difficulty, and of the greatest possible importance, for on it hangs the whole future of the gigantic scheme.

Let us assume that it is fixed that the rate of traveling through the tunnel shall be forty miles an hour; then half an hour will be occupied by each train in going through. The line will, of course, be worked on the block system, that is to say, no train will be permitted to enter at the Dover end until the previous train has come out at the Calais end, or *vice versa*. This would allow forty-six trains a day each way, an hour being reserved during which no trains would run, in order that repairs might be carried out. This is the maximum possible number of trains without an intermediate block; but for obvious reasons it would not be safe to count on this number, and thirty-six trains in twenty-four hours are as many in all probability as could be run. If no greater number

passed through the tunnel, it is clear that no dividend could possibly be paid unless the tariff were so high as to be prohibitive. We shall not stop to ask whether more demands will arise at any reasonable tariff than thirty-six trains a day each way would satisfy. If more trains are to be run, then a block station must be made about the middle of the tunnel, and we do not envy the lives which signalmen at this station would enjoy. It is not necessary here to go into any calculations as to the power required to propel the trains through the tunnel. Let us suppose, for the moment, that it will be worked by ordinary locomotives with 17 in. cylinders, 24 in. stroke, and four-coupled drivers 6 ft. diameter, the goods engines being almost identical, except that they would have six-coupled wheels 4 ft. 6 in. diameter. The consumption of coke by the passenger engines would be about 30 lb. per mile; the goods engines would probably burn 45 lb. Let us take the average consumption all round at 35 lb. of coke per mile; this represents, at the least, 24+35=840 lb. of air ruined for the purpose of supporting life or combustion per mile per train; or, in other words, about 320 cubic feet of air per pound of fuel, or 11,200 cubic feet per mile run. But apart from this, each pound of coke burned represents $3\frac{3}{8}$ lb. of carbonic acid. That is to say, we should have per mile per train 127 lb., or about 520 cubic feet, of carbonic acid gas discharged into the tunnel. The open air contains a variable volume of carbonic acid amounting on the average to from three to six parts in 10,000. When the proportion increases to twelve or fourteen parts in 10,000, as in crowded theatres, the atmosphere becomes exceedingly unwholesome. If fifteen or eighteen parts of carbonic acid in 10,000 were found in the air of the Channel Tunnel, passengers would suffer seriously. To bring up the proportion to this point, however, it is only necessary that the engines should give off carbonic acid gas in the proportion of twelve parts in 10,000, the other three or six parts already existing in the atmosphere outside. Now the cross section of the double tunnel will be about 500 square feet, and the cubic contents per mile will be 2,640,000 cubic feet; the engines will each discharge, as we have seen, 520 cubic feet per mile, which would suffice to raise the proportion by about $\frac{12}{10000}$. Three trains would suffice to bring the carbonic acid to the highest limit consistent with comfort if no ventilation took place. But counting the double service, seventy-two trains would pass through the tunnel in twenty-four hours, or three trains per hour, from which it will be seen, that to secure proper ventilation the entire contents of the tunnel should be renewed every hour. But the tunnel is twenty miles long, and as all the air must be withdrawn from either one end or the other, this would mean that a current of air moving at the rate of twenty miles an hour would have to be passed through the tunnel, which is, for obvious reasons, impossible. If we were content to let the condition of the air become very bad, it would be possible to get on, perhaps, by changing the air at half the preceding rate, but even then the velocity of the current would be ten miles an hour.

No doubt these figures appear startling, and we shall be asked how it is possible to carry on the traffic of the Metropolitan Railway, which is not traversed by a current moving at ten miles an hour? The answer is that there are dozens of ventilating openings in the Metropolitan tunnels, and that the distance between the stations where the ventilators are very large is extremely moderate. Thus, to change all the air within an hour in a piece of tunnel one mile long, it is obvious that the current needs to move at but one mile an hour, because a cubic foot of air entering at one end would at that velocity escape at the other after the lapse of an hour. But in the case of the Channel Tunnel it will be seen that every cubic foot of fresh air which entered, say, at Calais would, in the course of one hour, be supplied with $\frac{12}{10000}$ of carbonic acid, at which time it ought to be discharged; but it cannot be discharged till it reaches Dover, and it ought, therefore, to travel at twenty miles an hour. The practical effect of ventilation in this way would be that, while the air at the influx end would be pure, that at the efflux end might contain $\frac{12}{10000}$ of carbonic acid. It may be argued that the Mont Cennis Tunnel, eight miles long, is satisfactorily ventilated: but the cases are not analogous. Comparatively few trains pass

through the Mont Cenis in the day; three in the hour would, as we have seen, require a current of but eight miles in sixty minutes. As it is, the ventilation is excessively bad, although from the great altitude of the tunnel above the level of the sea, strong winds play about the end of the tunnel, and no doubt powerfully promote the passage of air through it. As regards the Channel Tunnel, no such condition exists; it could not be worse situated for natural ventilation. We do not assert that it is impossible to produce a current at the rate of ten miles an hour through it by furnaces or fans; but we do assert that the cost of keeping either fan or furnace going, which has to get rid of some 25 millions of cubic feet of air per hour, will form no inconsiderable item in the working expenses. Indeed, the difficulties which stand in the way of ventilation are so great that it will, in our opinion, be out of the question to use locomotives burning either coal or coke, and the propulsion of the trains must be obtained in some other way. It would be impossible, however, to discuss properly the possibilities of Channel Tunnel propulsion within the limits at our disposal just now. We shall return to the subject. Our purpose at present is to prove by a few figures that it is, to say the least, unwise to assume that the ventilation of the tunnel can be left to take care of itself. Unless the atmosphere is pronounced pure and wholesome, the tunnel will never enjoy favor with a travelling public, and nothing connected with the tunnel would prove more reassuring than the supply of ample evidence that its projectors are prepared with a well-digested scheme for sending plenty of fresh air into it. On this point, however, as we have stated, a somewhat ominous silence prevails at both sides of the "silver streak." It is perhaps time that this silence was broken.

NEW METHODS IN TOPOGRAPHICAL SURVEYING.

By Prof. A. S. HARDY.

Written for Van Nostrand's Magazine.

While in Paris during the winter of 1874, the attention of the writer was called to the extensive application of photography to topographical engineering, as practised by the French engineers. This fact was pointed out in the Reports of the U. S. Commissioners to the Paris Exposition of 1867,* with a brief description of the principle under which the process was conducted, but so far as the writer is aware of, the method has received no practical application in this country, nor the attention which is its due. The value of topographical maps, especially in railroad surveys, is too well known to be insisted upon, and the aid they have rendered in France especially is very notable. Any process by which the time, and thus expense, of a topographical survey may be reduced, has therefore a peculiar value in this country where the magnitude of the work has proved, as it were, a dead weight to any extended project of this nature. The photographic process, for example, would be invaluable in the projected survey of the State of Massachusetts, and will amply repay the brief study which its novelty demands. It has long been the practice in hydrographic and topographical surveys to make sketches of the shores or landscapes, on which are written, near prominent points, their angular distances measured by an instrument. This was extensively practised in the hydrographic surveys of the West coast of France, and notably also in the surveys made during the voyage of the "Bonite." In the report of the Abyssinian Commission made to the *Académie des Sciences* in 1846, M. Arago urged the adoption of panoramic views, with the angular distances between prominent points (one of which should be exactly located), inscribed thereon, as a prevention against errors and a precious source of reference for all time. Even as far back as 1802, a Commission had been appointed by the French War Department

* Vol. V. Report on Photographic Apparatus, p. 11.

to study this subject, and its report* contains the following remark: "The Commission believes it always useful and often necessary, in topography, as in the other arts, to add to the horizontal projection or plan which constitutes the map, a vertical projection or perspective, and desires that when possible this may never be neglected, even when at the time its utility is not apparent."

The first systematic study of this subject was made by M. Laussedat of the Engineers. For this purpose, he employed, in 1854, Wollastin's Camera Lucida, under a slightly modified form to avoid parallax. Subsequently, in 1861-2, this study was extended to the Camera Obscura. With the assistance of Capt. Ducrot and others, M. Laussedat used the process to be described in numerous extended surveys, and it is to the courtesy of the latter, now Colonel of Engineers, that the writer is indebted for many details which are the fruit of experience alone.

As evidencing the economy of this method in time, reference may be made to the work done in Savoy and the Vosges. In the former department, one survey of 18 days field work sufficed for 30,000 acres, contour lines being mapped 5 meters apart, giving 5 months' office work. In another case, 110 proofs were taken for 20,000 acres, the field work consuming but 15 days. These examples are taken at random from among many instances to show the relative time required by this and the usual method. This will depend somewhat, of course, upon the character of the country, but M. Laussedat has not found that it requires more than one-third that by the ordinary triangulative and often less. In the field work alone the economy is very apparent. The instrument employed is a combination of the camera and theodolite. The camera proper carries on its front face the usual objective, mounted in a sliding tube, so that the focal plane may be made coincidental with the sensitive plate at the rear of the chamber, and this tube is provided with the usual diaphragm to insure the distinctness of the images. A cover similar to that of the telescope excludes the light, but should slide easily on the objective without disturbing the instrument when leveled. Once focussed, the position of the tube may be marked, as it will not be necessary in landscape views to readjust it, as for near and distant objects. The grooves in which the slide containing the sensitive plate moves should be constructed with care, so that the latter may exactly occupy the focal plane. Within the chamber are placed four fine needles, one in the middle of each side near the slide, destined to intercept the light, thus marking on the proofs four points, which joined, give a horizontal and vertical line through the center of the field of view, whose use will be shortly noticed.

The chamber is supported in the usual way by two cylinders, one solid and fixed to a tripod with leveling screws, the other, hollow and enclosing it, is fixed to the chamber. The chamber may thus be revolved about the vertical axis with the hollow cylinder which carries a vernier reaching a graduated limb fixed to the inner axis. An 8-inch limb with a minute reaching vernier is sufficiently accurate for all operations which are to be graphically reprinted.

On one side of the chamber is a telescope and level. This telescope has a motion about a horizontal axis, and carries in its revolution a vernier reaching a vertical limb fixed to the side of the chamber. The plate on which this arc is engraved is one piece with the axis, which projects simply far enough to permit the vertical motion of the telescope. This apparatus, as well as the objective, may be dismounted for packing in a separate box as usual, and a counterpoise on the opposite side of the chamber insures stability when mounted. The adjustments of this instrument are obvious:

1st. The axis of rotation of the telescope must be vertical. In the instrument seen by the writer there were but three leveling screws, and the horizontal limb was so constructed that when the zeros of both verniers were at the zeros of their respective limbs, the level was parallel to a line, joining two of the screws. The adjustment was then readily made with the leveling screws and tangent screw to the telescope. This construction, common to French instruments, is of course unessential.

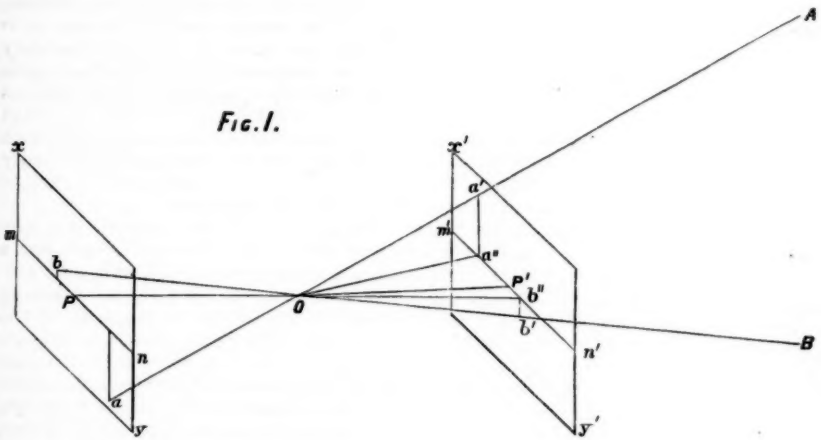
* Mémorial du Dépôt de la Guerre. Vol. II. p. 11.

2d. The line of collimation of the telescope, which is provided with both cross and stadia hairs, is effected as usual.

3d. The optic axis is made horizontal as in the ordinary geodesic instruments, and the reading of the vernier after adjustment is the error of collimation, to be added or subtracted, according to its sign, to the vertical angles subsequently taken. Two important conditions must be fulfilled by the maker: (*a*) When leveled, the axis of the telescope and the optic axis must be at the same height and thus describe one and the same horizontal plane during the chamber's revolutions; (*b*) The slide at the rear of the chamber, when in position, should be vertical and perpendicular to those axes.

It is thus seen that the instrument differ from those ordinarily in use only in a few details dependant upon their combination, and its use requires a knowledge of only the simplest principles of scenographic projection. Indeed, the proofs are themselves conical projections, the optic centre of the line, which is the vertex of the cone, being the point of sight, and, as in landscape views, the objects represented are so far distant as to have their images formed on the same focal plane, the distance of the point of sight remains constant.

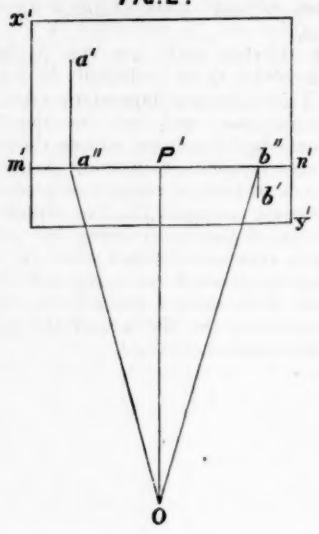
Fig. 1.



Thus let *O* be the optic center of the objective, its axis *O P* being horizontal, and *x y* the glass slide at the rear of the camera, occupying the focal plane. Then *O* is the point of sight, *P* the principal point, m n the horizon, and any two objects as A and B will appear at a and b. If a glass *x' y'* were placed between the objective and the landscape, and at a distance from *O* equal to *O P*, the representation would be similar to that on *x y*, and will in part correspond to a *positive* proof.

If the perpendiculars be let fall from *a'* and *b'* upon the horizon *m'n'*, and their feet joined with *O*, then will *oa''* and *ob''* be the projections on the plane of the horizon of the visual rays *OA* and *OB*, the angle *a''ob''* will be the angular distance between *A* and *B* reduced to the horizon, while the angles *a'oa''* and *b'ob''* are the angles of elevation or depression of objects above and below the horizon. All points of the landscape at the same level as *O* will appear on the horizon, the curvature of the earth, unimportant in such operations, being neglected. The proof is thus a conical projection whose point of sight is the center of admission of the lens, and the distance of the point of sight from the plane of the picture is the principal focal distance.

FIG. 2.

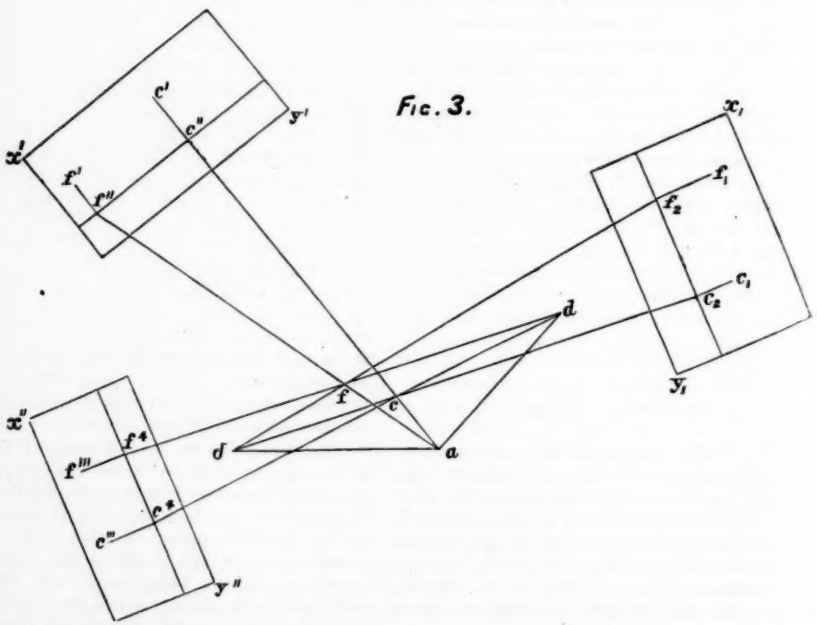


If then $x'y'$ be a photographic view on which the position of the principal point P' and the horizon $m'n'$ is known, as well as the principal focal distance of the lens, let the plane of the horizon be revolved about $m'n'$ until coincident with the plane of the picture. O will be found at a distance from $m'n'$ = principal focal, and is the revolved position of the point of sight. Join the foot of the perpendiculars $a'a''$ and $b'b''$ with O, then $a'ob''$ will be the horizontal angle between the objects having a' and b' for their images, *i. e.* the angle usually measured in the field. Finally, the vertical angle of any object as that whose image is a', is obtained by the ratio $\frac{a'o''}{ou''}$, its trigonometrical tangent.

Both the vertical and horizontal angles are thus determined from the vicus.

Suppose, now, a base line ab measured in the field, as also two angles cba and cab on any prominent object as c, and

FIG. 3.



that abc be the plot to any convenient scale. Having two angles and a side, the distances ac and bc may be computed. Suppose also two views $x'y' + x_1y_1$, taking one from a and one from b, and both containing the object c at c' and c_1, respectively. Having let fall the perpendiculars $c'c'$ and c_1c_2, let the proofs

be revolved about their horizons into the plane of the picture, and the points of sight placed at a and b respectively. Join c'' with a and c_1 with b, and revolve each wire about a and b respectively till $c''a$ and c_1b pass through the point c previously determined. In this position any object on both views may be located on the plan. Thus, one whose images are f' and f_1 will be found at f, the intersection of two lines af'' and bf_2 drawn from the points of sight to the foot of the perpendiculars $f'f''$ and f_1f_2. It is thus evident that a great number of points may be determined without further direct measurement. The plot is verified as usual in the method of intersections. A third view x'' y'', taken at any point as d and containing the object c, is placed in position as before so that the line dc_4 passes through c. A line joining d and f_4, should pass through f. Once verified in this manner, all views containing objects thus fixed can be placed in position. M. Laussedat, however, finds it preferable to measure each base, and to take either one or two angles to fix the position of each proof. Usually the angles between the bases and the angle between the base and principle point are measured. All other objects which are to be represented on the plot are located from the proofs.

To determine the height, of f'' for example, suppose the focal distance $1^{\text{m}}.5$, and let $af''=1^{\text{m}}.55$ $f''f'=0^{\text{m}}.05$, and and $af=0^{\text{m}}.55$, and the scale be $\frac{1}{8000}$. Since $f'f''$ is the apparent height of f' at the distance af'', and $af\times 8000$ its true distance, from the proportion

$$af'' : af\times 8000 :: f'f'' : x$$

we have

$$x=af\times 8000\frac{f'f''}{af''}=.55\times 8000\,\frac{.05}{1.55}=141^{\text{m}}.9$$

Hence the height of any object above the extremity of a base is found by multiplying the tang. of the angle of elevation (to a radius equal to the distance of the station from the foot of the perpendicular through the object) by the true distance as found on the plot. To this product the height of the instrument must, of course, be added.

The heights are also verified by performing this operation with reference to two stations a and b, whose difference of line is known. It is not necessary that this difference be measured in the field, since any difference in line between two sections will be indicated on the proofs by a change in the position of the horizon, and may be therefrom determined.

This horizon is indicated on the picture by the shadows of the needles already mentioned as placed within the camera. These needles are adjusted by the maker, but are held in small pieces moving in grooves, so that their re-adjustment is always possible. To effect this, it is only to be remembered that when the instrument is in adjustment and revolved, the axes of the camera and telescope describe the horizon, so that if during this motion the intersection of the cross hairs be fixed on any object, its image on the glass slide will fix one point of the horizon, and by turning the instrument to the right and left till the object is brought to the edges of the slide, two points may be there marked, and the shadows of the needles should fall on the line which points them. The position of the needles giving a vertical through the centre may be verified on the positive proof. Except in case of accident this adjustment, if made by the maker, need not be repeated.

If, as is usual, the objective is fixed in the middle of the front of the camera, the horizon will divide the proof into two equal portions. M. Savary has modified this arrangement by making it movable in two vertical grooves, one of which is graduated to permit the measurement of the displacement. In very mountainous districts the position of the horizon on the proofs may thus be changed. When the point of sight is above objects whose images do not fall within the limits of the proof, the horizon should be lowered and *vice versa*. The line marked by the needles will then indicate a parallel to the horizon, which may be drawn parallel to this line and at a distance from it given by the graduation near the objective, whose zero of course corresponds to that position in which the horizon is given by the needles. As the image is reversed, when the objective is raised the horizon must be drawn below and *vice versa*. Ordinarily the views do not cover all the field, and this simple expedient permits the increase of the field of view in certain cases without increasing inconveniently the dimensions of the apparatus.

The distance of the point of sight from

the picture, *i. e.* the focal distance of the objective, may be found from the triangle $a''P'O$ (a'' being any object on the horizon), by the formula

$$OP = a''P' \cot a''OP'$$

$a''P'$ being measured on the proof, and the angle $a''OP'$ by the horizontal motion.

The question has probably already occurred to the reader, to what extent does spherical aberration prove a source of error in the use of the camera obscura? For objects distant from the centre of the field of view will not have their images formed *exactly* in the principal focal plane. The very able researches* of Col. Laussedat on this subject, published in 1864, show that in the clearest manner for all ordinary cases, where the apparent heights of objects above the horizon on the view are small, the vertical component of the angular deviation (which is the same in every direction, everything being symmetrical about the optic axis) may be neglected. So that except in rare cases the trigonometrical tangent, already given, is taken as the measure of vertical angles. The horizontal component, however, cannot be neglected. With a simple achromatic objective of 0m.081 diameter, and a focal distance of about 0m.5, and a diaphragm of 0m.015 opening, 0m.077 in front of the nearest lens surface, the focal distance was found to differ slightly with the position of the point a''. Thus for a point 0m.605 from the principal point, the focal distance was 0m.505, but for a point near the border of the field of view, 0m.1476 from the principal point it was 0m.500. That is the focal distance diminished as the point from which it was calculated receded from the principal point. Evidently, then, if in the construction of the plan the focal distance was used as found by a point near the centre, the error would increase as the instrument was turned, and in 360° would reach in the above case 4°. If, however, we use for focal distance that calculated from a point near the border of the field, the error does not multiply; near the principal point and borders it is altogether insignificant, and midway between is a maximum, where in the above case it would not depress 5 minutes.

* Mémorial de l'Officer du Genie, No. 17, p. 278.

Without corrections, therefore, an exactness is obtained by this precaution more than sufficient for graphic constructions.

After what has preceded, the following *résumé* will be clearly understood:

FIELD WORK.

This includes first the measurement of the bases and angles. The notes are kept in five columns in which are recorded: 1° the position of their stations; 2° the length of the bases; 3° their included angles; 4° an angle measured between the base and any point in the field of view, serving to fix the position of the views on the plan. (These may be the principal points.) 5° Remarks.

The base may be measured by the chain. With the 12½-inch telescope, seen by the writer, and adopted as a good size for a camera whose horizontal dimensions are 16″×18″, bases not excluding 1,000 feet may be measured to within less than $\frac{1}{100}^{th}$ by the stadia. The stations are best chosen on the borders of the survey on dominant points, but central ones may be necessary, and in an extensive survey are selected very much as in ordinary triangulation, those being the most advantageous which are sufficiently elevated to unmask more distant objects. Stations near together are to be avoided, as the bases are thus short as compared with the lines of intersection which fix the objects on the plan, and therefore intersect under an acute angle. Should this be unavoidable, a simple method of avoiding inaccuracy will be indicated in the description of the office work. The photographic operations do not need description here. It may, however, be said that the French engineers prefer the use of paper to glass, which is fragile and heavy in extended surveys. The positions thus obtained, though less distant usually than those obtained with glass, are sufficiently so.

Finally, in certain localities, as among buildings or in depressions, slight sketches will complete the details and obviate a multiplication of views.

OFFICE WORK.

Inasmuch as the focal distance is the scale of the views, it bears a relation to the scale of the plan. M. Laussedat states that experience has shown a focal distance of 0m.5 best adapted for scales

between $\frac{1}{2000}$ and $\frac{1}{15000}$. The distance at which one may operate also depends upon the scale. Suppose the scale chosen is $\frac{1}{5000}$, then a focal distance of 0m.5 will represent on the plan 1,500 metres and points at a much greater distance from the station will not be obtained with the desirable precision. Were the scale $\frac{1}{8000}$ however, the operations could be conducted at 4,000 metres. The bases are just plotted with the protractor, and at each station is laid off the angles, taken from the notes, between the base and principal points of the several views. On each of these lines is laid off the focal distance, and at their extremities a perpendicular drawn, which is the trace of the plan of the picture.

A distant position serves for the determination of the focal distance. With this distance for a radius, the trigonometrical tangents of 1°, 2°, 3°....15° are calculated (a field of 30° giving the best results) and these distances are laid off each way from the centre of a horizontal line on a separate piece of paper. Through the points of division perpendiculars are then erected, and the descents of the same angles to the same radius computed, they being the length of the risual rays between any object and the point of sight, reduced to the horizon. Finally parallels are drawn to the horizon at equal distances apart. This diagram is then transferred to all the proofs taken with the same objective, taking care to make the coincidence between the horizontal line and the vertical through the centre, and the horizontal and vertical line through the principal point on the proof exact. Every point is thus referred to the horizon and vertical line, and the length of its vjsual ray reduced to the horizon is known.

To fix any point on the plan, its horizontal co-ordinates on two proofs are transferred by the dividers to the horizons on the plan, and their extremities joined with the proper points of sight. To determine the heights we have already deduced the formula

$$x = s\,d\frac{h}{d'} \quad \text{in which}$$

x = true height sought, h = apparent height $f'f''$ (Fig. III.), $s\,d$ = true distance af, s being the denomination of the scale, and d' = the apparent distance af'', or the visual ray reduced to the horizon.

As in this formula d' is the secant exactly calculated and s is given, any error that may arise will be due to d and h, the former being measured on the plan, and the latter on the proof. Both of the errors due to d and h will then be multiplied by the fraction $\frac{s}{d'}$ and therefore are proportional to the scale and focal distance. Furthermore, any error in h, being multipled by d, will be greater as the object is further off. Views should then be taken as near as possible to objects where heights are desirable. For distances less than 550 yards the error will not exceed one foot with an objective of 1.64 focal distance. For extended surveys in which the contour lines are 10′, 15′, or more feet apart, all desirable accuracy is obtained with the above precaution, while, as already shown, an accuracy more than sufficient for graphic construction is obtained for the plan.

The office leveling notes are kept in eight columns as follows: In the 1° Designation of the points whose heights are sought.

2°. d'—the calculated descent or visual ray.

3° sd—the true distance taken from the plan.

4° $\mp h$—the apparent height, taken from the proof.

5° $\pm x$—the real height calculated from the formula.

6° The height above the plane of reference of the stations to which objects are referred.

7° Absolute height above plane of reference.

8° Remarks.

In operating upon bases small as compared with the visual rays, construct, on training paper, for each station a few horizontal angles for objects as distinct and far apart as possible, and fix these constructions on the plan as usual. Should the intersections not prove perfect, and if the angles have been carefully constructed, by very slightly moving the papers in succession, their position after a few trials may be completely rectified. The principal lines may then be marked lightly on the plot in pencil.

The leading operations and principles of the method have now been described.

Both M. M. Ducrot and Laussedat have compared at different times the results of this method with those obtained by an ordinary survey on the same ground, and found them remarkably exact, even on very difficult ground. The advantages of this application of photography are evident. No sketch can compare in completeness or exactness with photographic views, and by no other means yet known can the time and labor of a topographical survey be thus abridged. In proportion as the survey is small and the greatest possible accuracy requisite, this method loses its superiority. But for larger surveys, its advantages are unquestionable, and in all cases may be made a valuable source of contribution to those details which would otherwise demand a long and tedious direct observation, and the photographs constitute a series of notes good for all future reference. As briefly exposed in this paper, it is regarded as the last used on this subject by French engineers, and in view of the probable increase in topographical surveying in this country deserves the attention of our own.

APPLIANCES FOR ENABLING PERSONS TO BREATHE IN DENSE SMOKE OR POISONOUS VAPORS.

By CAPT. SHAW, Chief Officer of the Metropolitan Fire Department.

From the "Journal of the Society of Arts."

Numerous attempts have been made, both in ancient and modern times, to enable persons to enter safely into places full of smoke or noxious vapors, but very few of the appliances employed for the purpose, even though apparently successful during experiments, have received the sanction of permanent use. Means have been invented to enable persons to pass through the flames of a furnace at nearly white heat, but they have been troublesome and expensive, and obviously so seldom likely to be of any use except for purposes of display or public entertainment, that they have naturally fallen below the level of practical criticism, and are only mentioned here as matters of scientific curiosity.

Our great enemies in this way are smoke, and those innumerable poisonous vapors created by intense heat under certain combinations well known to chemists, but too abstruse to be explained here, which we designate under the general title of mephitic gases.

The vapors which we find dangerous probably include nitrogen, sulphuretted hydrogen, carbonic acid gas, choke damp, and numerous other defined and well-known gases, but it is unnecessary to enter here into the chemical details or to be very precise as to the terms by which these vapors are designated in laboratories, as I mean simply to include under the general head of mephetic gases, all those vapors we meet in our business which will not permit respiration to continue within their range.

To enable a man to enter into and remain in a place strongly impregnated with mephitic or noxious gases, two courses are open. One is to supply him with pure air from an external source; the other to provide him with the means of filtering for himself such air as he finds, admitting to his lungs only that which is pure and useful, and rejecting the rest.

I will now endeavor to describe a few of the best known appliances for this purpose, including long breathing tubes, air bags, and short tubes, smoke jackets, smoke cap, woolen filter, and fireproof clothing, and I will take them in the order here given, commencing with the long breathing tubes.

Long breathing tubes.—For supplying air from external sources several modes have been tried, among others what were known as breathing tubes, one leading from the external air into the mouth and nose, the other leading outward from the mouth and nose, with a mouthpiece and nose valve arranged for the purpose. This, in certain cases, has proved efficacious, but the working of it requires not only practice but an amount

of attention which it is difficult to keep up, and when the inlet or air-pipe has to be very long, and to go round curves, the labor involved in breathing is sometimes considerable. Why this should be so I cannot say, as the pressure of the external atmosphere ought to be ample and more than ample to overcome the friction in the pipe; but it has occurred, and does occur, and therefore ought to be mentioned. Another application by these tubes, is by means of a mouthpiece alone, with two openings, which can be closed alternately by the tongue, the nose being stopped with a nose-pincers. This also has proved successful in very simple cases and for short periods, but it is evident that it would not do for our rough work and rapid movements. It is quite correct in principle, but is probably best adapted, in practice, to the purpose for which it has been much used abroad, namely, to enable persons to breathe under water in certain baths which require the immersion of the head. Attempts have also been made to work with a pipe leading merely from the man's mouth to the ground, but they have been unsuccessful, and when not unsuccessful have been useless, as a man generally is on his hands and knees on such occasions, and then does not require the pipe, or if he is standing up, he has only to stoop down and obtain such clear air as there may happen to be available.

Air Bags and Short Tubes.—Another mode is to carry into the smoky place an inflated bag of air, with two tubes of the kind already described connecting it with the mouth, one tube leading from the bottom of the bag or reservoir, and the other to the top, the tongue acting as a valve. In this case the man inhales through the tube leading from the bottom, and exhales through that leading into the top, and the discharged air being warmed, and consequently lighter, remains for a time on the top, and mixing with the remaining air, may be inhaled again several times. with such an apparatus working properly a man can remain in the foulest air several minutes, but it is obvious that he must be very careful in the management of the breathing tubes.

The Smoke Jacket.—One of the safest appliances for the supply of air to a person working in a smoky or vitiated atmosphere is that known for many years in most English fire brigades as the smoke jacket, and abroad as the *blouse contre l'asphyxie, appareil á feu de cave*, or in some places as the *appareil Paulin*, from the name of its supposed inventor. The smoke jacket consists of a blouse of cow-hide, pliable, light, and mounted with a hood, which completely envelopes the man's head. It is mounted in front of the face with a pair of eye-glasses, or a half cylindrical sheet of glass firmly fitted to the front of the hood so that the wearer can see every thing in the place to which he has penetrated; and underneath the mask there can be, if desired, a whistle fitted with a valve, which serves for giving signals. Straps and buckles, called bracelets, hold the sleeves round the wrists, and a thong, called a *cuissiere*, or leg-strap, which is fixed in front, and, after passing between the legs, is buckled behind, prevents the blouse rising. It is, besides, held over the hips with a leather girdle, on the front of which a lamp can be carried when required. On the left side is fixed a screw, to recieve the corresponding screw of a hose which is of the same pattern as those of the fire engines, and communicates at the other end with one of these engines. The pump of the fire engine being set to work, of course without water, drives air into the jacket, swells it out and keeps the man in a compressed atmosphere, which is continually renewed. The surrounding air cannot penetrate, being continually driven back by that escaping at the wrists and other openings. Once inflated the blouse holds enough air for a man to be able to breathe in it without difficulty for six or eight minutes, but it is necessary to continue working the pumps, in order to enable him to remain inside any length of time. When the lamp is lighted, air is introduced to it by means of a little pipe communicating with the inside of the jacket.

This smoke jacket is very useful for extinguishing fires in vaults, stopping conflagrations in the holds of ships, and penetrating wells, quarries, mines, and cesspools, &c.; any place, in short, where the air has become unfit for respiration. The special advantages of this jacket are its great simplicity, its

facility for use, and the rapidity with which it can be carried about and put on; but its drawback is, that it requires the use of an engine, or air-pump, and consequently is of no service to one man alone. for this latter reason, smoke jackets, although very effective for enabling us to get into convenient places for extinguishing fires have very rarely proved of any avail for saving life.

Wherever vulcanized india-rubber tubes are used for the purpose of conveying air to the lungs, I should recommend very great caution, as it is undoubted that, at least in some cases, men have been known to suffer serious inconvenience, if not to incur considerable danger, from inhaling through this material. This is, however, a very trifling difficulty, and I have no doubt has only to be pointed out to be speedily obviated by improved construction.

The Smoke Cap.—Another apparatus, and one free from the disadvantage of being dependent on aid for its use, is the smoke cap, which is very light and portable, and can be brought into use in a few seconds by a man working alone.

A smoke cap is an apparatus by means of which a man is able to breathe when working in dense or poisonous vapors. It partially closes the nose, and provides for the mouth a light, closely-fitting filter with valves, and for the eyes a complete cover, which will act as a protection, without obstructing the sight, the whole being capable of being put on and completely adjusted for use in a few seconds by the man who is to wear it, without aid from any one else.

It is desirable that it should be strong and fit for rough work, also that it should contain no delicate parts likely to get out of order, and no material parts inaccessible for immediate examination.

Every one of these requirements may be separately carried out without much trouble, where the questions of time and rough usage can be put out of consideration; but the combination of the whole for rough work, and the shortness of the time available in our business for adjustment, have hitherto constituted very serious difficulties, which however, it may be hoped, are now, to a great extent, if not altogether, overcome.

The filter, which separates the pure air from smoke or noxious vapors, and which constitutes the specialty of the apparatus, is the invention of Professor Tyndall, who has in the kindest and most liberal manner placed it at our disposal, solely from public spirit, and without fee or reward of any kind whatever.

The first complete apparatus as now issued was designed and made up by ourselves in the workshops of the Fire Brigade, and served as the pattern for those afterwards furnished by contractors.

The smoke cap consists mainly of two parts, called respectively the hood and the respirator.

The hood is made of the best dressed calfskin blacked, cut in sections, and closed with air-tight joints, each part overlapping the next to an extent of half-an-inch, and the sections strongly sewn together with two separate rows of saddlers' stitching. The skull part is fitted to the shape of a man's head, and is about 24 in. in circumference at the widest part; underneath this there is a band about 2 in. deep forming a collar, to the lower edge of which there is attached a kind of yoke or apron-piece about 6 in. deep, shaped to fit on a man's chest and shoulders under a tunic.

To facilitate the putting on and taking off of the hood, there is an opening down the whole of the back part from the crown to the neck, and on each side a row of four eyelet holes with brass bushes, through which there is rove as a lacing a leather thong, the ends of which go round to the front, and after passing through a small metal ring, are knotted at the ends below two hard wood knobs, to prevent their being pulled back through the ring. When the hood has been put on, the thongs are pulled in front, and, rendering through the eyelet holes, draw the whole of the skull part close to the head. The opening at the back is fitted with a piece of what is commonly known as waterproof sheeting, a thin air-tight material which occupies very little space, and, although wide enough to allow the head to enter freely, is easily folded away by the drawing of the thongs. The lower flap or apron part is tucked in under the collar of a tunic, so as to form an air-tight joint sufficient for the purpose.

To the front of the hood inside is attached, by means of round-headed brass rivets, a frame or piece of tinned sheet metal, shaped to fit the front of a man's face from the bridge of the nose to the chin. Opposite the mouth there is attached to this frame a piece of brass, with a circular opening, cut on the inside with a female thread to take the male thread of a hard wood mouthpiece, and on the outside with a male thread to take the swivel screw of a respirator. The male screw to which this swivel is coupled has cut inside it a recess in which a leather washer is placed, so as to make an air-tight joint when the coupling is screwed up.

At a distance of about 4 in. above the mouthpiece there are fixed a pair of curved eye-glasses of the best clear glass, set with cement in brass rims with lugs, which are attached by screws to curved metal frames riveted on the inside of the hood.

The respirator consists of two parts, the valve chamber and the filter tube.

The valve chamber is formed of a piece of best drawn brass tube 2 in. long and 2 in. in diameter, with an upper and lower valve plate, and between the two a slotted horizontal opening to which is soldered on and riveted a brass connecting piece about $\frac{1}{2}$ in. long, fitted on the end with a swivel screw to match the outer mouthpiece screw on the hood.

Each of the valve plates is fitted with three ebonite ball valves, $\frac{1}{2}$ in. in diameter, turned perfectly round and without the slightest projection or rim in any part. The openings in the plates are $\frac{1}{16}$ in. in diameter, and are so cut that the seatings embrace at least one-third of the valves. The seatings, which are separate pieces screwed into the plates, and are most carefully beveled out so the valves shall make an exact fit, are neither so tight as to stick nor so loose as to allow leakage. The valves are properly protected above by metal guards, which allow a lift of $\frac{1}{8}$ in. for suction and a shade less for delivery.

Above the delivery valves there is screwed on a nut or cap plate, which protects the valves and guards from injury, and is pierced round the edge with 28 holes for the escape of the discharged air.

The filter tube is also of brass, of the same diameter as that used for the valve chamber, and is 4 in. long. Across the upper end inside there is soldered on a piece of fine copper wire gauze with $\frac{1}{16}$ in. mesh, to prevent wool or other light substances passing, and over the lower end there is screwed on a brass ring or cap with a similar piece of wire gauze.

The whole of the respirator is tinned inside and lacquered outside.

The following parts of the respirator are screwed on to each other, and are therefore capable of being quickly and easily separated for examination and cleaning when necessary:

1. The lower cap which has a female screw, and is joined to the male screw on the bottom end of the filter tube.

2. The whole of the filter tube, which has two male screws, the one at the bottom to take the cap, and the one at the top to join a female screw cut underneath in the cylindrical or outside part of the suction valve plate.

3. The suction valve plate, which has two female screws, the one at the bottom to take the top male screw of the filter tube, and the one at the top to join a male screw cut on the lower end of the valve-chamber tube.

4. The valve-chamber tube, which has two male screws, the one at the bottom to take the top female screw of the cylindrical part of the suction valve plate, and the one at the top to join the covering plate or top cap.

5. The top nut or cap plate, which has a female screw to receive the male screw at the upper end of the valve-chamber.

The charge for the filter consists of the following materials, which are put in with the tube turned upside down, and, of course, the lower cap removed:—Half-an-inch deep of dry cotton wool, an inch deep of the same wool saturated with glycerine, a thin layer of dry wool, half-an-inch deep of fragments of charcoal, half-an-inch deep of dry wool, half-an-inch deep of fragments of lime, and about an inch deep of dry wool.

These must be packed so closely as to fill every part of the chamber, and they should be pressed down as lightly as experience shows to be compatible with facility of breathing through them when in use. After this the lower grating cap is screwed on, and the filter is then ready for use.

Alteration in Arrangement of Charge for Smoke Cap Filters.—The following refers to changes which have to be made in the arrangement of the charge for the smoke cap filters, as before explained.

Experience has shown that the fragments of lime which are put in for the purpose of absorbing carbonic acid, become reduced to powder merely from the effects of the atmosphere, and are often quickly slaked by a man's breath. As these particles when pulverized render breathing very difficult, and it has been thoroughly ascertained that in fires carbonic acid is very seldom present in sufficiently large quantities to cause actual danger, it has been determined to remove the lime altogether, and to rearrange the other materials.

I have accordingly altered the arrangement as follows:—Half-an-inch deep of dry cotton wool, an inch deep of the same wool saturated with glycerine, half-an-inch deep of dry wool, an inch deep of fragments of charcoal, and an inch deep of dry wool. The other arrangements remain as hitherto.

It is of course to be understood that whenever carbonic acid is known or suspected to be present, a layer of fragments of lime may with advantage be added for immediate use, a corresponding portion of dry wool being removed for the purpose; but in such cases it is advisable to remove the lime shortly after use, and to replace the wool as before.

Each particle of smoke is in fact a piece of solid carbon or charcoal, carrying in it, and with it, a small load of noxious vapor, which produces greater irritation in the throat and lungs than even the solid particles; and there is always present in smoke some carbonic acid, which, though generally at our work in small quantities, is occasionally found sufficient to cause both trouble and risk to those inhaling it.

The dry cotton wool acts with great effect as a filter, arresting the larger portion and coarser particles of the opaque smoke.

The wool, moistened with glycerine, acts as a finer filter, arresting that portion of the opaque matter of the smoke which, from its tenuity, escapes arrest by the dry wool.

The charcoal arrests the invisible pungent vapors existing in the smoke, which no mere mechanical filtration would effect.

The lime absorbs the carbonic acid produced by the combustion or burning.

The succession of the layers may be changed without prejudice to the action, but for such rough business as ours it is well to have some dry wool in at least the following places, namely, on top, to prevent the taste of the glycerine, charcoal, or lime penetrating into the mouth, between the charcoal and lime to prevent their mixing, and at the bottom, to prevent the charcoal or lime falling out.

To prepare for putting on the smoke cap, take off the helmet, open a few of the top buttons of the tunic, and turn over the collar, breast, and back as low as possible without interfering with the free movements of the arms.

To put on the cap, hold it with the face part downwards, open the lacing sufficiently to allow the head to pass in, and taking the lower part of the sides or flaps in both hands, with the knobs and the ends of the thong hanging down, slip the hood over the head, and, as soon as the top rests on the crown of the head, adjust the wooden mouthpiece in the mouth, which will bring the eyeglasses and other parts in their proper places; tuck in the lower flaps under the tunic, take hold of the thongs in front, and pull on them until the lacing at the back draws the skull part close to the head all round.

It is not actually necessary to knot the ends of the thong in front, but it is convenient to do so, and in any case they ought to be tucked inside the breast of the tunic, lest they should catch in anything at work. After this, turn up and button the tunic, put on the helmet, and then all is ready.

Whenever convenient, it will be found a great advantage to plug the nostrils with pieces of any soft material that may be available, and thus prevent exhalations from the nose, which have a tendency to dim the glasses.

It is almost needless to mention that the hood may be put on with or without the respirator, as the latter can be coupled on and removed equally well whether the hood is on or off.

For practice the whole should be done by the man himself, without any help whatever.

With valves so very small and light as those necessarily used in an apparatus which is carried on a man's head, there is always more or less danger of their sticking in the seats or guards, especially when subjected to the combined action of heat, and of the vapor and water from a man's mouth; but this danger is generally obviated without any difficulty by the man either tapping the side of the respirator with his hand, or jerking his breath and blowing out any water which may have accumulated in the valve chamber.

The cap, with all fittings complete, is carried in a circular tin case about 10 in. long and 6 in. in diameter, with a capacity of 282 cubic inches, or less than one-sixth of a cubic foot.

The weights of the several parts are as follows:

	oz.	lb.	oz.
Hood with mouthpiece, thong, &c.		1	4
Respirator:			
Top cap	1¼		
Valve chamber tube, with top valve plate, valves, guards, connecting piece and swivel coupling	7¼		
Lower valve plate with valves, guards, and cylindrical part	2½		
Filter tube, with top grating	5		
Lower cap of filter tube	1		
	—	1	1
Charge		0	3
Tin case		1	8
Total		4	0

Summary of Weights.

	lb.
Hood and fittings	1¼
Respirator charged	1¼
Total as worn	2½
Tin case	1½
Total as carried	4

The Woolen Filter.—This is a very simple contrivance, but one more frequently used than perhaps all the others together. When none of the appliances previously mentioned can be obtained, a man who has to enter smoky places will find a great advantage in placing over his mouth and nose any woolen or other substance which will act as a filter, and intercept the grosser sooty particles of smoke.

Fireproof Clothing.—In connection with this part of the subject, though, as already explained, rather as a matter of scientific interest than of practical usefulness, the following description is given of an apparatus for enabling a man to pass through a furnace, and even to remain in it for several minutes.

Description of the Appareil Aldini.—In certain cases it may be indispensable to traverse flames in order to reach some particular spot, and it was for the purpose of preserving persons who find themselves in such circumstances that the Chevalier Aldini, an Italian physician, thought of the apparatus which bears his name.

This preservative apparatus consists of two vestments, one composed of a thick tissue of asbestos (*amianthus*), or woolen stuff, made incombustible by means of a saline solution, the other of a metallic cloth of iron wire covering the first garment, and mounted with a helmet on its upper part.

A person enveloped in these two garments can withstand the action of flames for some minutes without experiencing any dangerous effects, for on the one hand the external metallic tissue cools the flames, and on the other hand the internal tissue transmits the heat very slowly on account of the want of conductibility in the substances of which it is composed.

Aldini's apparatus dates at least from the year 1825, but, notwithstanding the good results which it has shown in the numerous experiments to which it has been submitted, it has never been adopted to any considerable extent, either because the circumstances in which it could be really of service are much too rare in comparison with the expense of its manufacture and maintenance, or because, as happens with a number of inventions, it presented in serious practice considerable inconveniences, such as rarely occur in experiments for mere show, where everything is generally arranged for the success of the operation.

The following is an account of one of the experiments made in Paris, in 1829, by some *sapeurs pompiers*, or firemen, with Aldini's clothing on: Two piles were erected of thin wood, covered with straw, ten yards long, two yards high, and distant from each other about a yard and a half; two lateral openings allowed the firemen to go out from the flames

if they were compelled to do so, and in other ways facilitated the experiment, which consisted in traversing half the length of the burning heap, going out by one of the lateral openings and entering again by the opposite end, and then repeating the same experiment from the other side of the heap. The four firemen who were to make this trial were clothed in the new garment of metallic tissue; two carried, besides, a clothing of asbestos (*amianthus*) over a cloth garment, rendered incombustible by borax, alum, and phosphate of ammonia; the two others had a double clothing of prepared cloth; each man had boots of asbestos, and under the foot a piece of cardboard of that substance; and one of them carried on his back a child, ten years of age, whose head was enveloped in a helmet of abestos. The firemen penetrated together into the interior of the double pile of flames, and, walking slowly, traversed it several times. At the end of 60 seconds, the child inclosed in the basket cried out so that the man who was carrying him was forced to retreat precipitately. They made haste to take out the child, who had in no way suffered; his skin was fresh, and his pulse, which beat 84 before the experiment, was only 96 after it. He could without any doubt have remained much longer in this wrapping, were it not for the fear which seized him, and which was caused by one of the straps supporting the basket having slipped a little on the shoulder of the fireman who carried it. The child, at the sight of the flames which roared below them, thought he had been thrown into them. A few minutes after he was as merry as usual. and felt no uncomfortable sensation. The fireman who carried the child had, before the experiment, 92 pulsations a minute, and after it 116. The three others remained in the flames 2 minutes and 44 seconds, and came out without having experienced anything except a sharp heat. The pulsations were before 88, 84, 72 a minute, and after 152, 138, and 124 a minute. The flame was continually fed with straw thrown upon that which was burning. There was very soon formed an enclosure of fire in which the firemen were shut up, and as a portion of the straw scattered on the ground threw up a flame which at times enveloped their legs, it was certain that the bodies of the men were exposed to the direct action of the flames. At a distance of more than six yards from the focus of the fire the heat was so intense that none of the numerous assembly could remain there. In other experiments the firemen were furnished with large shields, which they made use of to keep back the flames. It is obvious that such an apparatus as this could be of very little use for general work.

I have now gone through the principal appliances I can remember for the purpose of enabling men to work in smoke and other dangerous places, confining myself chiefly to some of those which have been to a certain extent brought into practical use, but adding one instance of what I must own to be rather a scientific curiosity than anything else.

There are thousands of other inventions which have been brought under my notice of late years in several countries, but none that I can remember at present which would be worthy of such consideration at such a meeting as this. It may be that in the discussion which I understand is to follow the reading of this paper, some new idea will be suggested, and, if so, I can only say that it will be heartily welcomed as an addition to the very small stock of knowledge which at present exists on the subject, and which, so far as my corps and I are concerned, would have been smaller still but for the cordial assistance we have received from my excellent friend, Professor Tyndall, to whom I beg leave to be allowed to offer my most sincere acknowledgments, not only for his generosity in giving us valuable information, which we have been enabled to turn to practical use, but also for his kindness and courtesy in supporting us by taking the chair on the present occasion.

ADVICES received recently from the United States report that large quantities of steel rails are being collected at New York by the Erie Railway Company, to be used in re-laying its track next year. At Chicago, also, a good inquiry is noted for steel rails, and there is a prospect of a considerable spring demand.

AMERICAN CARTOGRAPHY.

By S. V. CLEVENGER.

Written for Van Nostrand's Engineering Magazine.

The rapid increase of population in the United States, and consequent growth of the nation in internal and maritime industries, has produced a demand for more accurate knowledge of the topography of our country than was afforded by the various Marco-Polo sources upon which, in olden times, we were content to rely.

From necessity there has arisen a multitude of incongruous cartographic offices attached to the different departments of the Government, in some instances, several such offices belonging to one department, no two of which have identical systems, all varying in the degree and kind of skill employed in records and delineations; and, with a few notable exceptions, all failing to provide results at all commensurate with the annual appropriations made by Congress for their maintenance.

The U. S. Coast Survey is the most valuable institution, both for the unsurpassed accuracy of its achievements and its judicious methods for disseminating the information it obtains.

This office has been evolved from the commercial growth of the nation and the imperative need for precise information for coast defence. Its present magnitude is indicative of the high estimation in which it is held, and the efficiency of its operations is due to the undoubted abilities of the officers in charge, aided by the best and only correct system in the organization of its corps of assistants, cadetship, special training, and life-long service.

It has been especially free from the degrading effects of political preferment in the selection of even its humblest *attaché*, and to-day stands a monument of What Should Be among the ruins of What Is, in our intriguing Babylon.

The Hydrographic Service would, in its nature, seem to be an adjunct to the Coast Survey; but it is not, and far from it, it is amenable to a different department, although these two offices are, in a measure, inter-dependent.

The National Observatory and Hydrographic Office were originally connected, an incongruity probably less absurd than the present want of homogeneity in the relations of the numerous cartographical offices of the Government.

It is probably fortunate for the Coast Survey Office that it is not a part of the Navy Department, but it is decidedly unfortunate for the Hydrographic Service that it is not under the direction of the Coast Survey, inasmuch as the former could not exist, except with enormous expense, were it not for the operations of the latter. The War Department endeavors to collate notes and charts from various sources and has much "surveying" done, such as the locating military roads and establishment of reservation boundaries, the maps of which, except where the work is supervised by graduates of West Point, or skillful engineers, which is rarely the case, usually evince an utter ignorance of simple arithmetic on the part of the person charged with the execution of the survey.

Then the Quartermaster's Department must needs have maps wherefrom may be estimated the amounts due for transportation at certain rates per mile over innumerable roads, and it is safe to assume that nothing like accuracy has ever been attained in the measurements of these roads—the practice being to compromise disputed distances, and the presumption being natural that a distance not disputed has in it something of the nature of collusion between parties representing interests.

The postal routes are depicted by the Post-Office Department on a large map compiled from sufficiently inaccurate sources to warrant no doubt as to its incorrectness in general, though no blame may be attachable to the officials supervising its construction. In this department, as well as the Quartermaster's, millions of dollars are expended with these distances, accurate or false, as an element of the expenditures, and the probabilities being strongly against their

correctness, it is not unreasonable to suppose that the government gains nothing by the errors.

The Engineer Corps, presuming it to be officered by graduates of West Point, trained there or elsewhere for proficiency in this special arm, is capable of being employed to greater advantage. Although its duties are, at present, somewhat restricted, the corps is not wholly kept from an occasional contribution to our geographical muddle. Considering all things, however, "Essayons" need not be ashamed of its maps.

It would be deplorable if the *ante bellum* efficiency of this service should be lowered by the admission of uneducated officers to any greater extent than has already been done.

An erratic system of geological explorations and triangations has gained something of a foothold which ultimately will become a well appreciated and valuable contributor to our cartographical lore. The results of several years surveys of this kind, made by different parties, civilian and military, are embodied in numerous hatchure maps with differing scales. Excepting the coast survey, the government has obtained the most information at the least cost from these explorations than from any other kind of surveys. The only objection to this class of work being the general one applicable to all—want of uniformity between different parties in their drawings and field notes, and the absence of anything like co-operation.

These parties are occasionally annoyed by an overlapping of areas, and surveys are re-made over fields previously traveled by another party. A commentary on the necessity for something approximating agreement and general design.

The Interior Department has charge of the execution of boundary lines between States and Territories, and the parceling out of public lands, adopting an independent and somewhat unique method of representing areas by sectional maps. Too much latitude is allowed contractors in running the lines dividing public lands to give maps thereof much importance beyond furnishing a good general idea of the country, and the difficulties in the way of a faithful representation of the surface, from this source is augmented by fraudulent work or "fudging" by the contractor.

This department must also have accurate statistics and maps of railroads, canals, Indian reservations, etc., which is not possible when the only exact knowledge we have of our interior is that it is somewhere within our coast line.

The public is by no means aware of the great amount of guess work resorted to by map compilers after searching all departments for information unobtainable, and what renders this condition of things inexcusable is that enough money has been expended by the government for surveys to have afforded a thorough survey of the entire globe.

The explanation of there not being a reliable map of the United States in existence, lies in the misdirected efforts of the many governmental offices, the want of organization and concentration of the numerous surveying bureaus, and what is most reprehensible, the fact that out of three thousand persons to-day employed by the Government, in geographical work, not more than three hundred know anything about the business, and these are principally members of the Coast Survey.

There is a remedy, and it is plainly indicated.

There should be a Cartographical office under the control of the Coast Survey Corps, or as efficient an organization as the Coast Survey, which cannot be found, and that office should have supervision of all surveys, whether geodetical, hypsometrical, hydrographic, or division of public lands.

Surveying, worthy of the name, is certainly not a *bagatelle* which may be intrusted to the unskilled workmanship of mediocre clerks. It is a science requiring considerable knowledge and special training, and when the coast, geological, hydrographic, land, postal, military, road, etc., surveys, shall have been consolidated into a thoroughly organized scientific bureau, then we may hope for some correct topographical information to be diffused at about one-third the cost to the Government of the present misappropriations.

ON THE THEORY OF IRRIGATION.

By FREDERICK CHARLES DANVERS, A.I.C.E.

From "Quarterly Journal of Science."

The great importance which the subject of irrigation has recently attained to in this country is no doubt primarily due to the forced necessity of utilizing our town sewage, and devoting it to profitable purposes, instead of, as has become the general practice, emptying into our streams and rivers, polluting their waters and destroying their fish. The advisability of adopting a system of irrigation in England has, however, of late years, become a necessity, and one which must annually increase in urgency, entirely irrespective of the subject of sewage utilization; and it is only by a proper appreciation of this fact, and of the causes to which it is due, that we can expect the subject will receive attention. In order to convey the full meaning of the foregoing remarks, it is necessary that we should consider, somewhat in detail, the true theory of irrigation, which will be found, as we proceed, to owe its origin to a disturbance, by the works of man, of the balance originally prescribed by nature between evaporation and precipitation.

A careful study of the works of nature, in their primitive state, cannot fail to show the beautiful harmony of creation, and the perfect economy of its arrangements whilst contributing only to the support of brute creation. To man, however, in his more elevated sphere, has apparently been given a certain power over the elements, by means of which he can disturb that harmony of existence, which not only is not violated, but is actually promoted by the lower orders of creation. The student of history, by applying this test in his researches into the records of past ages, will find that to man alone may be attributed such a disturbance of the balance of forces as, in progress of time, has led to serious convulsions of nature, affecting not only the geography of the earth, but also many atmospheric and climatic changes in different parts of the world, the occurrence of which there can be no difficulty in establishing. "If* we compare the physical condition of certain ancient countries at the present day with the descriptions given by old historians and geographers, of their fertility and general capability of ministering to human uses, it will be found that more than one-half of their whole extent—including the provinces most celebrated for the profusion and variety of their spontaneous and their cultivated products, and for the wealth and social advancement of their inhabitants—is either deserted by civilized man and surrendered to hopeless desolation, or at least greatly reduced in both productiveness and population."

There are two great primary causes which, above all others, may be said to have led to these remarkable changes; and these are, first, the destruction of forests; and, secondly, surface and subsoil drainage. We shall consider briefly these two subjects in the order in which they are mentioned above, and then proceed to show in what manner their evil effects may best be remedied.

It has been stated above that in the absence of human interference the natural law of consumption and supply keeps the forest growth, and the wild animals which live on its products, in a normal state of equilibrium,—and the perpetuity of neither is endangered until man interferes to destroy the balance, and this he does, not wilfully, but in order to contribute to his necessities. Thus, when the means of subsistence began to fail on such ground as had been left open by nature—and which must first have been subjected by man for the supply of his necessities—and as population increased, recourse was necessarily had to the removal of a portion of the forest that stood in the way of further extension of cultivation. A small quantity of wood only being required for fuel and buildings, fire was most probably resorted to in order to clear lands for agriculture, which method, as is well known even at the present day, renders the ground beneath especially suited for vegetation. Such indiscriminate destruc-

* "Man and Nature," by George P. Marsh; 1864, p. 3.

tion of forests necessarily caused a disturbance in the economy of nature by affecting the temperature and humidity of the atmosphere, thus causing considerable climatic changes; by influencing the local distribution of rainfall; and by its affect upon the flow of springs.

"Forests," says Becquerel,* "act as frigorific causes in three ways:—1. They shelter the ground against solar irradiation and maintain a greater humidity. 2. They produce a cutaneous transpiration by the leaves. And—3. They multiply, by the expansion of their branches, the surfaces which are cooled by radiation. As these three causes act with greater or less force, we must, in the study of climatology of a country, take into account the proportion between the area of the forests and the surface which is bared of trees and covered with herbs and grasses. We should be inclined to believe *a priori*, according to the foregoing considerations, that the clearing of woods, by raising the temperature and increasing the dryness of the air, ought to react on climate. The observations by Boussingault leave no doubt on this point."

With regard to the influence of forests upon humidity, it must be remarked that the vegetable mould, resulting from the decomposition of leaves and of wood, whilst it helps to obstruct the evaporation from the mineral earth below, absorbs the rains and melted snows that would otherwise rapidly flow away. This moisture it subsequently parts with gradually by evaporation and percolation. The water absorbed by the roots of a large tree has been found to be greatly in excess of the weight of that fluid which enters into new combinations resulting in its growth, and the superfluous moisture must somehow be carried off almost as rapidly as it flows into the tree. "Recent experiments† on this subject by Von Pettenkofer were made with an oak tree, extending over the whole period of its summer growth. The total amount of evaporation in the year was estimated at 539.16 c.c. of water for the whole area of its leaves. The average amount of rainfall for the same period was only 65 c.c.; and the amount of evaporation was thus 8½ times more than that of the rainfall." This evaporation of the juices of the plant, by whatever process affected, takes up atmospheric heat and produces refrigeration, increasing, at the same time, the humidity of the air by pouring out into the atmosphere, in a vaporous form, the water it draws up through its roots.

Although the destruction of forests can hardly be said to influence the total amount of rainfall, it has, no doubt, owing to the circumstances above mentioned, no small effect upon its distribution. The most obvious argument in favor of this supposition is that the summer and even the mean temperature of the forest is below that of the open country adjoining. This must reduce the temperature of the atmospheric stratum immediately above it, and, of course, whenever a saturated current sweeps over it, it must produce precipitation which would fall upon or near it.

The manner in which forest destruction has most directly led to the necessity for irrigation, is, perhaps, the effect which it has upon the flow of springs. The roots of forest trees penetrating far below the superficial soil conduct the water accumulated on its surface to the lower depths to which they reach, and thus serve to drain the superior strata and remove the moisture out of the reach of evaporation. This ensures the permanence and regularity of natural springs, not only within the limits of the wood, but at some distance beyond its borders, and so contributes to the supply of an element essential both to vegetable and animal life. As the forests are destroyed, the springs which flowed from the woods, and, consequently the greater watercourres fed by them, diminish both in number and in volume. Boussingault, in his "Economie Rurale," remarks that, "since the clearing of the mountains in many localities, the rivers and the torrents, which seemed to have lost a part of their water, sometimes suddenly swell, and that, occasionally, to a degree which causes great disasters. Besides, after violent storms, springs which had become almost exhausted have been observed to burst out with impetuosity, and soon after to dry up again." Arguing from the basis of facts already established, he draws the

* "Des Climats et de l'Influence qu' exercent les Sols Boisés et Non-Boisés."

† "Quarterly Journal of Science," October, 1870, p. 524.

conclusion that forests have a special value—"that of regulating, of economizing in a certain sort, the drainage of the rain-water."

To sum up the results consequent upon the clearance of forests, as already set forth, it may be briefly stated that any undue extent of interference with the economy of nature in this respect cannot but be followed by the drying of the vegetable mould on the surface of the ground affected by the clearance; and it soon becomes removed by the alternate action of wind and rain, leaving behind a sterile soil, possessing none of the properties necessary for cultivation; but not, fortunately, beyond the power of man to restore, in course of time, to its former powers of reproduction. The means for effecting this are the same which, if adopted earlier, would have prevented its falling into a state of sterility, viz., the artificial application of water to the soil, so as to counteract, in some measure, the consequences necessarily arising from an interference with the proper proportion prescribed by nature of forest to open land.

Having now considered the effects caused by the destruction of forests, we have, in the next place, to trace, in a similar manner, the probable evil consequences of land drainage.

Surface-drainage is a necessity in all newly-reclaimed lands, and probably dates its origin from the commencement of agriculture; but the construction of subterranean channels for the removal of infiltrated water, marks ages and countries distinguished by a great advance in agricultural theory and practice, a large accumulation of pecuniary capital, and a density of population which creates a ready demand and a high price for all products of rural industry. Under-drainage being most advantageous in damp and cool climates, where evaporation is slow, and upon soils where the natural inclination of surface does not promote a very rapid flow of the surface waters, it is not surprising to find that this practice has been carried further, and a more abundant pecuniary return obtained from it, in England than in any other country.

By removing water from the surface of the soil, however, the amount of evaporation is necessarily lessened, and the refrigeration which accompanies all evaporation is diminished in proportion. Accordingly it is a fact of experience (as stated by Marsh in his "Man and Nature" previously referred to) that, other things being equal, dry soils, and the air in contact with them, are perceptibly warmer during the season of vegetation, when evaporation is most rapid, than moist lands with the atmospheric stratum resting upon them. Under-drains, also, like surface-drains, withdraw from local solar action much moisture which would otherwise be vaporized by it, and, at the same time, by drying the soil above them, they increase its effective hygroscopicity, and it consequently absorbs from the atmosphere a greater quantity of water than it did when, for want of under-drainage, the soil was always humid, if not saturated. Under-drains, then, contribute to the dryness as well as to the warmth of the atmosphere, and as dry ground is more readily heated by the rays of the sun than wet, they tend also to raise the mean, and especially the summer, temperature of the soil.

Although the immediate improvement of soil and climate, and the increased abundance of the harvests have fully testified to the advantages of surface and subsoil drainage as adopted in England; its extensive application appears to have been attended with some altogether unforeseen and undesirable consequences, very analagous to those resulting from the clearing of the forests. The under-drains carry off very rapidly the water imbibed by the soil from precipitation, and through infiltration from neighboring springs or other sources of supply. Consequently, in wet seasons, or after heavy rains, a river bordered by artificially drained lands receives in a few hours, from superficial and from subterranean conduits, an accession of water which, in the natural state of the earth, would have reached it only in small instalments, after percolating through hidden paths for weeks or even months, and would have furnished perennial and comparatively regular contributions, instead of swelling floods to its channel. By thus substituting swiftly acting artificial contrivances for the slow methods by which nature drains

the surface and superficial strata of a river basin, the original equilibrium is disturbed; the waters of the heavens are no longer stored up in the earth to be gradually given out again, but are hurried out of man's domain with wasteful haste; and while the inundations of the river are sudden and disastrous, its current, when the drains have run dry, is reduced to a rivulet.

It has thus been shown that a great similarity exists in the consequences arising from the destruction of forests and from land-drainage, both as they affect the temperature and humidity of the atmosphere and soil; which, in their turn are, with a good show of reason, supposed to have a considerable effect upon the distribution of rainfall, though not, perhaps, upon the actual amount of it. It is impossible to restore the harmony of nature thus once disturbed, without allowing the lands, cleared and improved, to revert to their original state; but as this would be detrimental rather than conducive to man's interests, it is more desirable that the balance should be restored in other ways, and by other means, which, whilst counteracting the evil effects above referred to, admit of the retention of the land in its improved state of productiveness. Thus, by the artificial production of moisture in the soil, by means of irrigation, the equilibrium may be restored; whilst the subsoil drainage which has in many cases rendered a resort to irrigation necessary, is in itself essential to the proper development of cultivation by irrigation; otherwise the land, especially in heavy soils, is liable to become waterlogged, to the injury alike of the crops and the health of the nerghborhood. This latter is clearly proved in the case of rice crops, which are so notoriously injurious to health that no European can with safety sleep in their vicinity. "Not only does the population decrease where rice is grown," says Escourron Milliago, "but even the flocks are attacked by typhus." This is happily not the case where simple irrigation is adopted for the growth of grass, cereals, vegetables, and other crops required in European countries generally, where proper attention is paid to subsoil drainage. The reason why land will not produce good crops in the absence of a sufficient amount of water, even though it be highly manured and otherwise well cultivated, is that moisture is essentially necessary for the admixture with the soil of those invigorating properties existing in manures, which, in the absence of that agency, would, though mechanically mixed with the earth, remain chemically separate and distinct from it, and, therefore, not in such a state as to be in any way beneficial for the development of growth in herbage or plants. With the assistance of water, however, the salts contained in manure are set free and eagerly unite with the soil, by which they may be said to be digested and prepared to become fit food for the nourishment of vegetation; but, even when so taken up, these salts are, during seasons of drought, held from vegetation with an iron grasp by the soil, from which moisture alone can again loosen them. Thus, we see that, whilst moisture is required in order to cause a chemical combination between the constituents of the manure and the soil, it is also further required before that soil will yield up the properties thus obtained for the purpose of vegetation.

Having now considered in what manner irrigation has been rendered a necessary adjunct to cultivation, it remains but to state briefly what steps are required for the conservancy of rainfall in order to render it most conducive towards a restoration of that balance in nature which previous operations of man have tendered so seriously to disturb. These are two; namely, the prevention of waste by storage, and the construction of channels for the proper distribution of water so collected, properly fitted with mechanical appliances for the regulation of the supply to different fields or districts as it may be required.

It is not the object of the present paper to enter into any account of the works or contrivances necessary for the collection and distribution of rainfall and drainage water; some brief allusion to what has been done in this respect, in former ages and in other countries, has already been made in the pages of this journal, but a complete study of the history and engineering nature of such works would occupy more space, and deserve more attention, than could be given to the subject in the concluding part of

an article which has already occupied so much space; it may, however, be considered of sufficient importance to form the theme for a separate article upon some future occasion. In conclusion, it may be remarked that the question of sewage irrigati n is one entirely distinct from that of simple irrigation by means of water alone; the purposes of the one being but the application of moisture to the soil, it in no way supercedes the necessity for manuring, whilst the former combines the application of manure together with irrigation. It does not seem at all probable that the two systems will ever be carried out in conjunction with each other, neither is it necessary that they should be combined. It is also clear that, whereas sewage irrigation is only practicable to a certain limited extent, and in localities bordering upon towns or places where a number of human habitations are congregated together, irrigation in its simple form may be adopted, to a greater or less extent, wherever land is brought under cultivation.

SOME RECENT DEVELOPMENTS IN THE TECHNOLOGY OF IRON.

From "Iron"

Among the traditional sayings handed down from generation to generation, as embodying the accumulated experience of centuries, none recur more frequently than those which enunciate with singular unanimity the unpalatable truth that adversity teaches lessons more valuable and indispensable than any we care to learn in times of brighter fortune. "The pupils of misfortune are the aptest scholars:" "Adversity is the road to prosperity"—such is the burden echoed through the proverbs of all nations and all times. There are, moreover, few of us who do not have frequent—often, as we think, *too* frequent—opportunities of putting the assertion to the test, and it is well for us if we prove its truth. Those engaged in the manufacture of iron—one of the most precarious as it is certainly the greatest of human industries—have now such an opportunity. They are passing through one of those periodically recurrent phases, if not of actual adversity, yet of considerable depression and stagnation, of which the duration may be indefinitely prolonged.

It seems, therefore, a fitting time to turn to account the enforced leisure which accompanies such negative crises, by reviewing the more recent developments of the science and practice of the iron metallurgy, with a view to their application on the return of more prosperous days, whose advent nothing would so much tend to accelerate, as an enlightened attention to those economic details by which alone the cost of production can be lowered, so as to enlarge again the now untowardly slender margin of profit. The more so, as there is no season so propitious to the improvement of plant, the trial of novelties, and the modification of processes, as a time of slackness. Under the high pressure of the past few years invention after invention has been developed, many being of approved practical value, and all aiming at the introduction of fundamental changes in the existing course of manufacture. A number of these inventions are of American origin, and we must look to ourselves lest we find the Americans, with their extraordinary natural advantages, aided by a practical ingenuity probably superior, and certainly not inferior to our own, not only driving us out of their own markets, but proving formidable rivals on neutral ground. Hitherto the United States, despite their enormous deposits of ore and fuel, have labored under the disadvantage of the fuel being, in the majority of cases, in situations far removed from the ore grounds. This is notably the case with the pure and abundant ores of the Lake Superior district. The rapid progress of railway building, and the discovery of fresh coal fields, together with the successful application of inferior fuel, tends, however, to reduce this drawback to a minimum. It is probable also that, when the excessive depression which now prevails in the States passes away, labor will be ma-

terially cheaper, and scientific methods will supersede much of that wasteful and careless practice which protection and an ever-increasing demand permitted, not only to exist, but to prosper. Simultaneously with a remarkable advance in the practical details of metallurgical appliances and processes, there has been a not less conspicuous extension of the boundaries of our theoretical knowledge. Since the publication, in 1864, of Dr. Percy's admirable treatise, which (with the exception of Truran's work, which deals with the subject almost exclusively from the engineer's point of view) was the first contribution of real importance to the technical literature of iron by the greatest iron-producing nation in the world, there has been hardly any effort to deal comprehensively with the additional facts and observations which have accumulated year by year, through the labors of a constantly increasing band of scientifically trained investigators. It is to be hoped that a new edition of Dr. Percy's work, embodying recent results and progress, may be soon forthcoming, so that we may have the advantage of his judgment on matters on which he is so well qualified to give an opinion. In the meantime, the meetings of the Iron and Steel Institute, as well as those of the various engineering and scientific societies, have served as an arena for the discussion of some of the more important questions thus raised, though the possibly unavoidable intrusion of personal feeling may at times have somewhat obscured the views and prejudiced the impartiality of the controversialists, and rendered the more desirable an independent retrospect of the conclusions actually arrived at. So important, however, are the interests involved in the proper appreciation of these investigations and discussions, that it may be well to examine *seriatim* the various chemical and technical considerations on which they depend.

The first and most important process in the manufacture of any metal is unquestionably its reduction from its ore. The only ores actually worked for the production of iron are the sesquioxide (better known as hæmatite, or brown hæmatite, the latter being a hydrated variety); the magnetic oxide, Fe_3O_4; and the carbonate or spathic ores, among the latter are included the clay ironstones so extensively worked in Wales, Staffordshire, and Cleveland, and the Scottish blackband. On calcination, the carbonates part readily with their carbonic acid, and are simultaneously oxidised, mainly to the sesquioxide (Fe_2O_3). Thus the question of reduction is practically narrowed to the consideration of the most speedy and economical means of depriving of their oxygen these two oxides, Fe_3O_4 and Fe_2O_3; and, indeed, the magnetic oxide is so rarely smelted in this country that we need hardly concern ourselves with any other than the sesquioxide, under the various physical conditions in which we find it. Unfortunately, however, the reduction is complicated, especially in the cases of the carbonates, which constitute the bulk of English ores, by the necessity of getting rid of the gangue or earthy matter intermixed with the ore. This earthy matter, consisting mainly of silicate of alumina and free silica, is infusible, unless its fusion be assisted by the presence of some body with which it may unite to form a fusible silicate. Lime serves this purpose admirably, and its presence not only assists in the formation of a sufficiently fusible slag, but also serves to prevent the loss of iron in the slag, which its protoxide would otherwise form with the silica. Should the gangue itself be calcareous, silica becomes the approximate flux. Obvious as are the theoretical advantages (hereafter to be more fully treated of) which attach to the *direct* production of steel and malleable iron from the ore, the *indirect* process, in which pig is produced, not only for foundry purposes, but also as a preliminary to the production of forge metal and steel, has, in England, owing in some measure to local circumstances, obtained a development so gigantic, to the total exclusion of the older bloomery furnace, that it clearly has the first claim on our consideration. It is, moreover, in the chemistry of the blast-furnace that the greatest strides have been recently made, establishing, indeed, such an advance on our previous knowledge as to remove the operations taking place in that elaborately simple, yet gigantic, structure altogether from the domain of mere technical empiricism. Among the more recent laborers in this field have been Gruner, Tunner, Schintz, and, above all, our countryman, Mr. I. Lowthian Bell. It is

chiefly to him that we are indebted for those precise determinations and logically-drawn conclusions which have at last given a sound experimental basis to our theorizing on the complicated changes which occur in the interior of the blast-furnace, while he has afforded the commendable example of a hereditary and successful ironmaster, not only organizing a well-conceived course of experimental investigations, but having the candor and sagacity to throw open the fruits of the experienced thus gained for the free use of his manufacturing rivals.

The changes of which the blast-furnace is the seat, regarded in their simplest form, are the oxidation of the fuel by the oxygen of the blast; reduction of the oxide of iron; carburization of the reduced iron; and, finally, fusion of the carburized metal with formation and separation of the slag. If, however, raw carbonates are used, their calcination, or the removal of their carbonic acid, takes place in the upper part of the furnace; while in all but freshly calcined ores there is present a certain amount of moisture, which is also expelled near the top of the furnace. Then again, there is the calcination of the limestone, in which form the requisite amount of lime is generally charged into the furnace. The reduction of silica, sulphates, and phosphates, is yet another minor operation, with which the ironmaster would be glad to dispense. One frequently finds the ingenuity of metallurgical writers displayed in the accurate division of the interior of the blast-furnace into horizontal zones, marked with regular boundaries, to the several spaces within which it suggested that each of these actions is confined. Thus we have the zone of preparation, of reduction, of carburization, and of fusion. The futility of this arbitrarily precise topography was pointed out by Dr. Percy, but its inaccuracy has been still further disclosed by subsequent observations, which tend to show that any division other than a distinction between the melting zone and non-melting zone would, except as a matter of convention and convenience, be groundless.

In each of the operations indicated—which, however, are far from exhausting the list of actual reactions—heat is absorbed or produced, and the theoretical simplicity of the reducing action is modified to an embarrassing extent. The agencies by which these effects of reduction, and heat-production, and carburation are effected are mainly carbonic oxide and solid carbon, the former playing the larger part. The cyanides and cyanogen, hydrogen and ammonia, nevertheless have a certain auxiliary influence on the results, while it will be seen that a comprehension of the modifying or negative action of carbonic acid is absolutely necessary at the outset. It will be the most convenient course to assume for the present the presence of these bodies, and examine their individual action upon oxide of iron before considering their relative importance in the actual operations. Dr. Percy disposes of the subject in the following paragraphs, which perhaps sufficiently summarize all that was then accurately ascertained on the subject: —"Sesquioxide of iron," says the doctor, "is easily reduced to the metallic state when heated to redness in contact with carbon, carbonic oxide, hydrogen, ammonia, or cyanogen. When reduction by any of these agents takes place at a comparatively low temperature, the metal is left in a pulverulent state; when the temperature is high a coherent mass of malleable iron is produced, which may be readily forged with the solid metal. . . . In reduction by hydrogen, magnetic oxide is first formed." This, with the exception of some observations on reduction by solid carbon, was about the limit of our acquaintance with the action of reducing agents on iron ores, unless we except Ebelmen's experiments on the changes which materials undergo in their descent through the blast-furnace, in which there were neither analyses taken of the gases, nor were the conditions such as to allow of reliable conclusions being arrived at.

It has been stated that carbonic oxide is the most operative of the various reducing bodies present, and it was to ascertain the conditions and modes of its action that Mr. Bell's experiments were chiefly directed. He found that on passing pure carbonic oxide over calcined Cleveland ironstone it began to be deoxidized at about 210 deg. C., but at this temperature only 28 per cent. of the oxygen present was removed in an hour. At about 415 deg. C., the proportion of oxygen removed in an hour was nearly 6

per cent. This latter temperature is that fixed by Gay Lussac and other experimenters for the first signs of reduction taking place. Now, this temperature is but little over that of the escaping gases of an average blast-furnace, so that, as far as their carbonic oxide is concerned, it might begin its reducting action from the moment of charging. By a six hours' exposure to carbonic oxide at something under this temperature, from 37 to 50 per cent. of the oxygen was removed. An exposure of 3¾ hours at a bright red heat cost the ore 90 per cent. of its original oxygen. By a longer exposure to a bright red heat, with carbonic oxide, the remaining 10 per cent. of oxygen was reduced in amount, but there always remains a certain small proportion of oxygen, which Bell suggests to exist as a suboxide, Fe_2O. This leads to the consideration of the mode in which the reduction by carbonic oxide is effected. It was discovered by Caron that carbon was deposited on oxide of iron when exposed to carbonic oxide at a temperature under redness, a fact independently observed by Schintz; Bell, however, carrying further these experiments deduces from them very important conclusions. He found that at a temperature but little over 200 deg. C. carbonic-oxide deposits on the oxide over which it passes minutely-divided carbon. It is, however, at temperatures bordering on 450 deg. C. that this phenomenon is most pronounced. The oxide at this temperature, soon after the commencement of the reduction, cracks, swells up, and is not only covered externally with a deposit of powdery carbon, but its interior is simultaneously penetrated with the fine deposit. M. Gruner and other French *savants*, who have repeated and studied these experiments, consider that the formation of metallic iron is necessary to initiate the deposit of carbon, but Mr. Bell believes that it is the presence of some suboxide which induces the splitting up the carbonic oxide. The weight of carbon thus deposited is very variable. In some cases the carbon deposited on hæmatite will equal five times the weight of the iron present. At other times, under apparently identical conditions, the carbon will be less in weight than the iron. In all cases the deposit on calcined Cleveland is immensely less than that on hæmatite or precipitated oxide. On the function of the deposited carbon there is also some divergence of opinion, but there can be little doubt that the carbon thus penetrating the oxide effects the removal of oxygen after the gas has exhausted its deoxidizing power. It would appear, however, notwithstanding Dr. Percy's dictum, that the last traces of oxygen cannot be removed even by the joint agency of the carbon and carbonic oxide at a full red heat; the deoxidation being only terminated when fusion has taken place. Carbon deposition, as would be anticipated, diminishes rapidly at temperatures approaching redness, and ceases entirely at a red heat. These researches throw considerable light on the discussion between Le Play and Gay Lussac as to the relative importance of carbonic oxide and solid carbon as reducing agents.

It is not surprising that the molecular and mechanical condition of the oxide should materially affect the readiness with which deoxidation overtakes it, and experience abundantly demonstrates that this is the case. Thus Fe^3O_3, precipitated from a solution by ammonia, is far more susceptible to deoxidation than any natural oxide, and carbonic oxide commences to reduce it at 150 deg. C. Of more practical value are observations on the relative behaviour of the natural ores, but in this direction there is a deficiency of experimental information, the greater part of Mr. Bell's experiments having been carried out on Cleveland stone. As instances of this differing reducibility we have—

							Original Oxygen.
Calcined Cleveland,	40	pr. cent.	iron,	exposed for	7½	hours to CO, losing at 410.C,	20 pr. cent.
Calcined Spathose Ore,	52	"	"	"	"	"	28 "
Lancashire Hæmatite,	40	"	"	"	"	"	57 "
Calcined Cleveland,	"	"	"	7	"	"	417.C, 9.4 "
Calcined Cleveland,	"	"	"	6	"	"	410.C, 37 "
Lancashire Hæmatite,	67	"	"	6	"	"	36 "
Elba Specular Ore,	68	"	"	6	"	"	17 "
Calcined Spathose Ore,	52	"	"	6	"	"	15 "

These results appear at first sight hopelessly anomalous, nor, indeed, have the apparent contradictions been satisfactorily explained. In one case we have a poor hæmatite deoxidized to thrice, and even five times the extent of Cleveland stone subjected to the same influences; in another we find a rich hæmatite actually less susceptible than Cleveland ore. Doubtless the difference in the results is in part due to a difference in the speed of the current of gas to which the ores were exposed; but the question being a vital one in blast-furnace economy needs further elucidation. Experimenting on further samples of the last four ores in the table above, with a gas current four times more rapid than that used in the previous experiments. Bell found the results considerably modified. Thus while the hæmatite lost 71 per cent. of its oxygen, the Cleveland lost only 50 per cent., the spathose 42 per cent., and the specular ore 18 per cent.

Metallic iron has also the property of dissociating carbonic oxide at temperatures between 300 deg. and a bright red heat, with deposition of carbon and the formation of an infinitesimal amount of oxide.

The action of carbonic oxide in reduction is greatly modified by the fact that the carbonic acid, which is the product of its oxidation, has on spongy metallic iron an oxidising influence; this action commences between 300 deg. and 400 deg., and becomes more energetic as the temperature rises, the product being, at the lower temperatures, an oxide or mixture of oxides, of indefinite composition. Spathic carbonates and the protoxide are converted under the influence of carbonic acid to the magnetic oxide. It will be readily recognized that this oxidising action of carbonic acid constitutes a formidable obstacle to the completion of deoxidation by carbonic oxide, and sets up an impassable limit to the theoretical reducing power of a given volume of carbonic oxide, varying with the temperature. A study of the action of mixtures of the two gases becomes essential, and confirms this conclusion. The point first to be determined is the relative proportion of carbonic oxide necessary to prevent carbonic acid exerting this oxodising influence on the newly reduced metal. At a temperature of something over 400 deg. C., or about that of the throat of the furnace, we find a mixture of equal volumes of the two gases is neutral; but at a red heat the oxidising tendency becomes predominant, while at a white heat it requires a dilution with nearly ten times its volume of carbonic oxide to check the oxidising effect of carbonic acid. We are thus prepared for the case which actually occurs in the blast-furnace, and on which the development of its ultimate economy reposes.

It is to be observed that the removal of the first portions of oxygen seems in all cases to be much more easy than is the case when the reduction has proceeded to a certain point, each remaining particle of oxygen seeming to cling with increasing tenacity to the metal. A mixture of one volume of CO with six of CO_2 removed in half an hour 6 per cent. of the oxygen in calcined Cleveland at a low red heat, and this appears to be the point of equilibrium beyond which the action will not proceed; but even when the CO_2 was reduced to twice the volume of CO the mixture only removed twice the amount of oxygen in thrice the time. At a red heat, calcined Cleveland hæmatite and spathose ore were alike reduced to the condition of protoxide by equal volumes of the two gases. This is a very noteworthy experiment, which, taken in conjunction with the circumstance that metallic iron, under similar conditions, became oxidised to the condition of protoxide of iron (a fact first brought into prominence by Debray), points distinctly to the conclusion that such a mixture at the temperature indicated would only take up one-third of the total oxygen in the ore. Further experiments lead to the important practical position that at about 417 deg. C. a mixture of 100 volumes carbonic oxide and 31 volumes carbonic acid exercises on calcined Cleveland ore an inconsiderable deoxidising influence, and that this influence is still more insignificant when the carbonic acid is to the carbonic oxide as 1 to 2, being hardly equal to a removal of 10 per cent. of the original oxygen in eleven hours, and in some cases the removal being considerably less. At a red heat, however, the reduction is more rapid and considerable.

RAILWAY SIGNALS.

From "The Engineer."

THE chairman of one of our most important railways recently stated that the introduction of the block system on that line would increase the working expenses by between £200,000 and £300,000 per annum, and he expressed grave doubts that this enormous expenditure would really diminish the number of yearly accidents or augment the safety of the public. We know that railway authorities one and all regard the block system with doubt, and look on it as something that has been forced upon them, and which they could do better without. This unanimity of opinion lends weight to the arguments on which it is based; and these last should not be dismissed, as they too often are, without due consideration. Broadly stated they are two in number. It is urged that the block system interferes grievously with the manipulation of traffic, especially on crowded lines and at busy seasons of the year, and no doubt this is to some extent true; but the safety of the public must be considered before all things, and if traffic cannot be carried on with as much ease to the officials and with as little cost to the railway companies when the block system is in use as when it is not, then the officials and the companies must rest content to do the best they can, and to, in a sense, sacrifice their interests for the protection of travelers. The second argument against the block system is that it does not do what it is intended to do, and we have reasons to believe that this statement is but too well founded. The defect lies, however, we think, not in the system, but in the way in which the system is worked, and it is our object now to call attention to this point.

Under the block system a line of railway is cut up into sections of various lengths according to conditions principally dictated by the frequency with which trains follow each other. On lines of small traffic, four, six, or even ten miles may intervene between one block station and the next, while on our metropolitan lines the distance is usually reduced to a very few hundred yards. The theory is that two trains shall never be found at one time on the same line of rails between any two block stations. If this theory could be carried into practice the block system would work perfectly, and no collisions could occur except in one way. If a tie bar broke it is possible for carriages or wagons to be left on the road, the train going on and passing the next station the signalman would give the line clear back to the next block, and the following train would then run into the carriages standing on the line. A collision of this kind, however, is not likely to take place, because the signalman at B ought not to unlock the line for A unless he saw that the train was complete. It may also be pointed out that the guard of that portion of the train left standing on the line would take measures to avert any train following him; but it is obvious that if an accident were averted in this way, the fact would go for nothing in favor of the block system, which would have no power to interfere once a train passed A on its way to B. If the signalmen are really vigilant and experienced no such accident as that which we have described ought to happen under the block system. But collisions, some of them of a very alarming character, do occur when apparently every precaution is observed, and that on lines where the block system is very carefully worked. Some of them occur because in station-yards and at junctions work has to be done to which the block system does not directly apply. But a very considerable proportion are due to another cause, which the block system ought to eliminate altogether. It may not be generally known that the Board of Trade investigate every accident, great or small, which has put the lives of passengers directly or indirectly in jeopardy. The particulars of these investigations, the evidence of the witnesses, and the report of the officer who conducts the inquiry are all printed with tolerable promptitude, and circulated pretty freely. They find their way to journalists with commendable regularity. A very moderate acquaintance with these documents will show that a surprisingly large number of

collisions occur under existing arrangements; some of them are very serious accidents; the fact that they are not all so is, of course, not due to the block system. It may be asked how such a state of affairs is possible. The answer is easily supplied. Collisions occur because drivers do not attend to the signals, or because the signals cannot be seen or do not act with decision. They are also sometimes due to a mistake on the part of the signalman. To this class of accident we shall not further refer here, we shall confine our attention to the mistakes made by engine-drivers and guards.

In very many instances when a collision occurs the engine-driver says the signal was all right, and the signalman says it was not, and it is a work of no small difficulty to decide between them. A rather bad smash occurred on a Northern railway not long since. The engine-driver and his fireman said—as usual—that the signal gave line clear; the signalman, as usual, said that it did not. An inspection of the signal showed that both parties were in a sense right; that is to say, the signalman could set the lever in his box at danger, while the semaphore gave a doubtful indication which might be interpreted either way. In many cases, however, there is no room to doubt that drivers do run past signals without seeing them. Thus, in a collision case recently investigated, the driver was trying to get some water into his boiler, the injector acting badly, while the fireman was bringing coal down on the foot plate. They ran past a signal undoubtedly at danger without knowing it. It is not, however, necessary to insist on a fact well known to all railway men. Trains are run in foggy weather on a very haphazard system unless the fog is so bad that detonating signals are necessary. Signals are passed and no one gets a glimpse of them; and the same thing often takes place even on tolerably clear nights. Indeed, the wonder is, not that signals are not seen, but that they are, if we consider the short time available for picking them out on a "dirty night," and the number of things to which drivers, stokers, and guards have to attend as well as to signals. We shall not attempt to dwell on minor causes which conduce to the obscurity of signals, such as placing them too high, or too low, or in a bad position. It is enough to say that none of these causes could operate effectually if it was not that railway signals as now made, whether on the block or any other system, apply to the sense of sight only. Here is the grand defect, and until this is removed the block system cannot secure that immunity from accident which it professes to be able to give us, and it is quite possible that as much as £300,000 a year may be spent on a great line without making traveling very much safer.

It will be urged, we know, that railway signals have always appealed to sight alone, and that precedent is absent as regards anything else; but the last argument is hardly true, because when it is obvious that signals might just as well have no existence as far as the sense of sight is concerned, the platelayers are sent "fogging." There is, we are glad to see, a gradual drift of opinion in favor of something more certain than the semaphore; not that the semaphore is to be got rid of, but supplemented. In a word, more senses than one of those on the foot-plate are to be appealed to. The doing of this is a very simple matter; if it were not it would have been done long ago. But, as usual, ingenious persons begin to make difficulties where none exist, and within the last few years we have received numerous proposals for making sound-signals, manifesting the most perverse ingenuity. A favorite device is, that locomotives are to make contact in passing signals, and electric bells are to be rung on the engine. A complex and bulky paraphernalia of galvanic batteries, commutators, and wires form an essential feature in these devices, which we should be sorry to see adopted. To Mr. Stroudley and Mr. Banister, of the Brighton line, is due the credit of being the first to introduce in a practical form a supplementary signal. The arrangement now on trial is so essentially simple and so directly appeals to railway perceptions that it could never have originated with an outsider. Engine-drivers are peculiarly sensitive to the state of the road over which they may be running, and they can detect an unusual jolt or jerk with the utmost precision. Mr. Stroudley avails himself of this sense of touch, so to speak, when the semaphore is set to danger, in the following way:—

Through a cast iron guard secured to the rail by two of the ordinary chair keys are passed two plates of thin steel about ¼ in. thick by 3 in. wide. They are placed horizontally about 6 in. apart. When the signal is put to danger the plates are pushed through the guard on to the top of the rail, on which they lie side by side. The wheels of the engine must pass over these plates if the driver neglects the signal, and in so doing he receives three specific jolts—one for each wheel. Nothing more powerfully arouses the attention of a driver to a sense of danger than an unusual motion on the part of his engine, and Mr. Stroudley's "jolter" signal is, therefore, far more certain to prove effectual than any red light or detonator. It is impossible for those on the foot-plate to make a mistake. If they run past the signal they must know that it is against them. So far, the device has worked perfectly. Sound-signals can also be given with great ease and certainty by making a light lever on the engine come into contact with a fixed stop interposed by the act of setting the semaphore to danger, and so blow a whistle or sound a gong on the foot-plate; but unless several matters of detail are carefully attended to this device cannot be applied with success. A design of the kind was submitted to us some time since, which is exceedingly neat and simple, and of which we may have more to say. One feature in the invention is that if a driver runs past a signal the fact is recorded against him.

We believe that the difficulties that lie in the way of adopting supplementary sound or touch signals are really very insignificant, and that without them the block system can never be considered approximately perfect. We pronounce no opinion as regards the merits or the demerits of the block system, except that an argument against it of considerable weight would be removed by extending the range of signal perception by calling in other senses than that of sight; and in shunting and yard work generally such supplementary aids will prove peculiarly valuable at night and in severe weather. We hold that it is better to do without an apparently good thing if it is complex and likely to get out of order; and we now urge upon railway authorities a consideration of our arguments in favor of the adoption of supplementary sound or touch signals, only because they can be almost elementary in their simplicity although perfectly efficient. If any one doubts that they would prove useful, we point to the reports of Colonels Yoland and Riche and Captain Tyler as our answer.

COTTON GUNPOWDER.

From "Engineering."

Under the above name another member was lately added to the steadily increasing family of violently disruptive compounds. This explosive is of the gun-cotton glass, although it differs greatly from gun-cotton proper, both in appearance and character, inasmuch as it is a fine powder of a pale yellow color, and, it is stated, can be exploded with a cap direct after having been saturated with 20 per cent. of water. It is in fact a perfected development of what was three years since brought before the public as Punshon's gun-cotton, which consisted of gun-cotton toned down with sugar, and possibly some other ingredient until it could be—and was in our presence—used in a rifle. But the cotton gunpowder of to-day could not be used in a rifle without bursting it, so local and so powerful is its action; neither is it at present intended to be so used, the company who are now manufacturing it confining their production to a material for blasting only, which they make in two strengths, Nos. 2 and 3, No. 2 being the stronger and adapted for hard ground in mining, and No. 3 for slate and other similar workings. This powder is manufactured on a commercial scale at Oare, near Faversham, where a large number of military and naval officers, scientific and mining gentlemen assembled recently to inspect the process of manufacture, and to witness some experiments to test its power and safety.

The first point—the manufacture—proved very interesting, as it showed how that from a mere laboratory experiment, the cotton gunpowder had passed through many phases until it had become capable of production in commercial quantities. The initial process as shown to the visitors, consisted in mixing together nitric and sulphuric acid, in which the cotton is steeped, 1 lb. at a time, after having been hand-picked and further cleaned by being passed through a scutching machine, and afterwards washed and dried. After remaining in the acid for about four minutes, the cotton is withdrawn, and the surplus acid squeezed from it under hydraulic pressure. It is said to bring with it 20 lb. of acid from the tank, 12 lb. of which are pressed out, the remaining 8 lb. being abstracted from it in a centrifugal machine, in which 6 lb. form a charge. From the centrifugal machine the cotton is sent alternately to two steeping tanks and centrifugal machines, and after the second washing and drying it is passed through a pair of coarsely set rolls, and subsequently through a pair set more finely. The fibres have now become finely divided into particles of gun-cotton, and in this condition are subjected to a lengthened washing in a tank of aërated water, the air being forced through the mass of liquid pulp by a fan blast. From the aërating washer the gun-cotton—for such it now is—is run into settling tanks and afterwards partially dried, when it is taken to an incorporating mill, consisting of a pan and pair of edge runners, in which it is triturated in company with one or two other chemical substances, which complete the combination termed cotton gunpowder. It now only has to be dried, and this is effected in wire gauze-bottomed trays placed over a channel through which a current of warm air is driven. From the drying house the powder is taken to the cartridge-filling sheds, and is made into cartridges, which are packed in cases and conveyed to the magazine. The magazine is situated some distance from the works, and is zinc-roofed and surrounded by a broad moat; zinc was preferred for the roof under the belief that if an explosion were to occur, the zinc would volatilize instead of being blown about in fragments.

The second point—the experimental trials—proved no less interesting than the first, inasmuch as it showed how that from a comparatively unsafe and unreliable explosive compound—as the gun-cotton was when we first saw it some three years since—it had become an apparently safe and reliable blasting agent of great power. And this, we should here mention, is due to the pertinacity with which Mr. Mackie, the engineer of the company and manager of the works, and M. Faure, their chemist, have stuck to the task of developing the invention into its present practical shape. Not less credit is due to Mr. Trench, who has had the practical carrying out of the works under the above gentlemen. The first series of experiments were intended to illustrate the safety in transport and storage of the cotton gunpowder and included the lighting of cartridges by ordinary means, when they simply burned quietly away, and the ignition of others by a capped fuse, when they exploded violently. Some cartridges were then capped with dynamite detonators which previously had failed to explode the cotton powder, which, as a rule, requires a more powerful detonator of special make. Wednesday, however, being a show day, the dynamite detonators, possibly not wishing to be outdone by their special brethren, in each case exploded the new powder, a point, however, which is of no great consequence either one way or the other. In order to show that explosion would not follow upon conflagraiton, two barrels of the new powder were placed each in a roaring bonfire, and after a time the barrels were burned through and the contents blazed harmlessly away. An iron pile driver weighing half a ton was then allowed to fall 15 ft. on to a box containing 10 lb. of the powder in order to illustrate immunity from danger in such cases as railway collisions, which, so far, it did, as the box was smashed and the powder scattered around.

The second series of experiments illustrated the strength of the powder, and consisted first in placing a charge of 2 oz. in a bore hole made in a block of Kentish rag stone measuring 5 ft. by 3 ft. by 18 in., the explosion of the charge cracking the stone in all directions. Four steel ingots weighing 8 cwt. each were next laid in a pile with 2 lb. of the powder

placed centrally between them. The explosion of the charges broke the ingots up and hurled the pieces to long distances. Other four ingots weighing 11 cwt. each were similarly treated with 2½ lb. of the powder with similar results. A cylinder of cast iron 2 ft. in diameter and 18 in. deep was charged in a central bore hole with 6 oz. of cotton gunpowder and fired, but the explosion only blew the hole through, driving a conical shaped piece out of the bottom. A 6 ft. length of 70 lb. steel rail was then laid on its side on bearings 4 ft. 6 in. apart, and in its groove ½ lb. of the powder was placed and tamped with clay. The explosion broke the rail into four pieces, throwing the two ends far apart. In military work the first illustration given was the cutting off a post of 12 in. by 12 in. timber—assumed to be a stockade post—with 2 lb. of the powder placed against its side. The application of the compound to land mines was shown by placing two boxes each containing 30 lb. of the powder in holes in the foreshore of the Swale—which flows by the company's works—covering them with 6 in. of sods and exploding them. The result in each case was the formation of a crater 22 ft. in diameter and 8 ft. deep, besides the demolition of some of the factory windows, a result, we need hardly say, which was more unexpected, than the other. To illustrate the statement that the powder could be exploded even when saturated with 20 per cent. of moisture, a box of the powder stated to be so saturated was placed on the beach and successfully exploded. The concluding experiment was the explosion of 50 lb. of cotton gunpowder suspended in the Swale in a case 10 ft. below water level. The explosion threw up a fine column of water some 200 ft. into the air, much to the satisfaction of the visitors, a satisfaction, however, not inferior to that afforded by the previous experiments, which demonstrated that a safe, handy, and powerful explosive was ready to be placed on the market. It has yet to undergo the test of time and experience in practical use, but from what we saw and heard of it on Wednesday there appears little reason to question its survival in these respects.

SCIENTIFIC SURVEYS.

From "Nature."

THE almost universal idea in this country of what constitutes a Scientific Survey goes no further, we believe, than the departments of Topography and Geology, and, as we are a seafaring people, the Hydrography of our coasts. We daresay many of our readers will be surprised to hear that some whose opinions in matters of this kind ought to have great weight, deem any survey totally inadequate which does not, to a greater or less extent, include nearly every department of science What are the prevalent notions on the subject on the other side of the water, may be learned from a Report just issued on a proposed New Survey of the small State of Massachusetts.

Last year the American Academy of Art and Sciences presented a memorial to the General Court of the State of Massachusetts, urging the necessity for a new Scientific Survey of the Commonwealth. It is forty years since there was a survey of the State; that was the first public survey in the United States, and included not only topography and geology, but zoology, botany, and agriculture as well. The biological surveys were so well done that some of the reports are even yet regarded as standard works, but the advances in all departments during the past forty years have been so great, that practically a new survey is required.

The suggestion of the new survey came appropriately from the principal scientific body of the State, and it is gratifying to see that the Legislature have such a respect for its opinion as at once to take action upon the suggestion. The memorial of the Academy was referred to the Board of Education, a committee of which took the wise course of calling to their council the most eminent men of science in the State, who could

aid them with their advice. The names of most of those who were called in to give the results of their study and experience are known to science all the world over; they are Professors B. Peirce, N. S. Shaler, and E. N. Horsford; President Clark, Dr. T. Sterry Hunt, Dr. Asa Gray, Dr. A. S. Packard, Mr. G. B. Emerson (who reported on the trees and shrubs in the former survey), Mr. Alex. Agassiz, Hon. Moses Kimball, Mr. C. F. Adams, Mr. S. H. Scudder, Mr. A. G. Boyden, and Mr. H. F. Walling.

The Report which has come to hand gives an account of the meeting between these eminent representatives of science, pure and applied, and the committee of the Board of Education. Each one freely expressed his opinion of the desirableness of the proposed survey, showed how it should be conducted so far as his own department was concerned, and pointed out the advantages which would certainly follow from a thorough survey. As might be expected, they are unanimously in favor of the proposed undertaking; and the immense advantages which were shown would accrue from it if carried out thoroughly in all departments, leave the State no alternative but to organize it as early as convenient.

A special committee from among the men of science named above—Messrs. Peirce, Sterry Hunt, Shaler, and Scudder—in their Report to the Education Committee recommend a scale of 1: 25000, or 2½ inches to the mile, as the scale which ought to be adopted for the survey; but this they do solely on the score of expense, admitting the superiority of the 6-inch scale. Prof. N. S. Shaler, in an impressive article in the March number of the *Atlantic Monthly*, strongly advocates the latter scale; for although the immediate cost would be at least double that of the smaller scale, still in the end it would be more economical; as, although the smaller scale would serve many useful purposes in the meantime, he declares it would be found that the survey would have to be repeated on the larger scale. We think the State of Massachusetts would be wise to profit by Mr. Shaler's hint, and accomplish the survey once thoroughly and completely on the larger scale, so that it would never require to be repeated. Indeed, the United States have had several lessons on this point; a considerable number of the States have been surveyed, but the surveys have all been more or less failures; there is not a single survey in this country," Prof. Shaler states, "which does not need at the moment to be done over again."

The practical advantages of topographical and geological surveys are so evident that it is unnecessary to point them out; no one, we presume, will deny that it is the interest and duty of every civilized country to obtain a complete and trustworthy knowledge of the extent, configuration, and composition of its surface. The important practical advantages which may result from a thorough geological survey has been well illustrated by a recent undertaking in America—the Hoosac Tunnel. It is Prof. Shaler's belief that "a due inspection of the surface of that ridge would have disclosed some of the difficulties encountered in the excavation of the tunnel, difficulties which would have been in a large measure avoided, had the engineers been forewarned. It does not seem too much to say that the cost of a complete survey, with a map on the scale of six inches to the mile, might have been saved by this easily gained knowledge."

But the State of Massachusetts has already had the wisdom to perceive that it is for the material advantage of the country that a knowledge of more than its topography and its geology should be easily accessible. To a thickly populated country, what can be of more moment than its hydrography, its water supply, which is also of so great importance in connection with manufacturers? In the proposed survey of Massachusetts a thorough knowledge of its hydrography will probably be considered as an indispensable part of the work. It seems almost a truism to say that in a country devoted to agriculture, an exhaustive scientific examination of soil would be a work of the greatest national advantage; such an examination has been to some extent made in Massachusetts, and the scientific men whose advice has been asked urge that it should be carried out over the whole of the State.

The practical advantages to be derived from a knowledge of the botany and zoology of a country, especially a country where agriculture is one of the staple

industries, seem almost equally apparent. If our farmers were well acquainted with all the plants and insects and birds which annually destroy so large a quantity of the cultivated produce of the soil, and at the same time knew how to meet their ravages, the saving to the nation would be enormous. Dr. A. S. Packard estimates that in Massachusetts alone they lose every year, from insects and parasitic plants, 500,000,000 dollars; and that in one year alone they lost by the army-worm 250,000 dollars' worth of hay-crops. No wonder he says, "Certainly it will be a good thing to have a body of observers at work systematically, year after year, collecting information, which may be spread before the farmers of the State and others interested." In this connection the words of Mr. A. G. Boyden are worth quoting:—

"The relation of the animal to the vegetable kingdom is a most intimate one. In the cultivation of orchards, garden vegetables, and things of that sort, upon which we as a people depend a great deal, we have to contend continually with insects; if we could learn, therefore, the facts about the insects that are found in this State; if we knew how they were generated, how they grow, and what they feed on, we might do a great deal towards saving a large part of the crops that are now destroyed by them. For instance, the canker-worm comes periodically, and very few people know much about the habits of this insect. Very little is known about insects by people generally. They do not even know them by name. They do not recognize an insect in the three stages of its life. Every gardner, every orchardist, every person cultivating herbs, trees, or shrubs, needs this information. As has been said this morning, we have not the books to which we can go for help in gaining this information. . . . Mr. Emerson has given us an excellent book on the trees of the State, which is a very great aid, but in respect to the other matters of which I have spoken, we have very few such helps as are needed. It would seem, therefore, that a survey of this kind, in which scientific men were employed, who could, as they went over the different localities of the State, collect, incidentally, and without adding very much to the expense, the facts relating to these subjects, would be of great value."

The body of evidence contained in the Report before us seems to us to show clearly, what indeed is almost self-evident, that one of the first duties of a nation, from the lowest point of view of self-interest, is to obtain a complete scientific knowledge of its home and all that it contains; only thus can it be able to make the most of its natural resources.

While the great practical advantages of the survey were insisted upon, the gains to science and to education which would accrue from it were also brought prominently forward. Some important problems in science, it was shown, might be solved by a thorough geological and biological survey of Massachusetts; one of the most important of these is in connection with Cape Cod.

"Here, in Massachusetts," Prof. Shaler says, "you have certain peculiar questions connected with the distribution of animal life to the north and south of Cape Cod which offers one of the most remarkable illustrations of the variations in the distribution of animal life that is afforded anywhere in the world. The constant changes, as years go by, the influence of temperature on the distribution of animals, these are questions which can be investigated there. There is no question that Cape Cod is one of the great problems of Massachusetts, and it is a problem on which a large number of investigations should be hung. Prof. Peirce, who has carefully traced and grouped the facts connected with that part of the coast, will agree with me in saying that Cape Cod is the key-point; that geologically it is the most important point in Massachusetts, with regard to the agencies that have been at work in the creation of the soil, especially with reference to the glacial period, &c."

With regard to education, it was shown that in several ways this exhaustive survey would be of great value. It was proposed by some that the scientific students in the several colleges might with advantage to themselves be occasionally employed on the work, while they might be of some assistance to the survey-parties; this plan, if judiciously carried out, might indeed be of great service both to the students and to the

work of the survey. Prof. Shaler pointed out that what he thinks the principal defect of the British Survey does not concern its work, but its effect upon British science. "It has not taken pains," he said—and we cannot take upon ourselves to judge of the justice of his statement—"to connect itself enough with the work of education in Great Britain; and the result is, as is admitted by some of the oldest geologists there, that there are few young geologists coming up in England at this time." This, if true, is certainly a great lesson for Massachusetts, as Prof. Shaler says; we hope, however, he has overstated the case, or at least that the supply of geologists in this country is not dependent on the Geological Survey. It was shown that in other ways a complete survey in all departments would be of the highest advantage in carrying on the practical education of the young in schools of all classes; and that from want of the results of such a survey, education was seriously hampered.

It will thus be seen that if in the course of years—for it is proposed to do the work leisurely and allow eminent scientific men to share in it as they can find opportunity—the people of Massachusetts do not have one of the most accurate and most complete surveys in the world, it will simply be because they are blind to their own real interests, which have so forcibly been brought before them by some of the most eminent of their scientific men, in whom the State is so rich. But as "the commonwealth of Massachusetts has not been wont long to weigh great advantages against small expenditures, so we may safely anticipate," with Prof. Shaler, "her speedy action."

Need we point any moral for ourselves from the liberal and comprehensive ideas which the comparatively small (its extent 7,800 miles, is only about that of Wales) and young State of Massachusetts has of what a survey of her territory includes? We have our topographical and our geological surveys, both doing excellent work, and both already productive of large practical and scientific results. But if we want to make the most of our small and over-crowded country; if we want, as we certainly should if we have our own welfare at heart, to have a complete knowledge of our country's resources, why should we stop short at topography and geology? Forty years ago Massachusetts showed itself to be far wiser than Britain is even now. Even then the little Transatlantic State saw it to be to its best advantage to know all about its soil and its natural products; we do not know that the question has ever been mooted in this country. A knowledge of what is being done on the other side of the water may give us a perception of our true interests, and our duty to ourselves and the world. To apply the words of Prof. Shaler: "Look at it as we may, measuring its immediate gains to our mines, our fields, our water-mills, to our cities in their water supply and sewage, to our railways and common roads, to the interests of each owner of an acre that is to be improved; or considering the remoter yet not less real economy which is found in increased knowledge of the Nature about us, and in the advancement of education, the reasons for this Survey are very strong."

THE Moscow-Brest Railway has been doubly unfortunate lately. Its traffic manager has just had a severe reprimand inflicted on him, in the official organ of the Ministry of Roads and Ways, for what amounts to general negligence in the service of the line, and its main station, at Moscow, has just been destroyed by fire. Admiral Possiett is said to have decided on augmenting the railways to the extent of 6,500 versts, which, with those already projected, will give 8,000 versts to be constructed. The works will be divided into four classes, and commenced in the order of their relative importance. The first lines to be taken in hand will be those to Siberia, and to the coal-fields of the Don. The Russian correspondent of the *Standard* says that the vexed question as to the northern or southern route for the Siberian line is not yet settled, but there are many signs which show that the southern route will be preferred. The Society to aid the Development of Trade and Industry in Russia has lately devoted a series of sittings to the details of this important commercial question, and, after discussion, resulted overwhelmingly in favor of the southern line.

RECENT IMPROVEMENTS IN THE MANUFACTURE OF PEBBLE-POWDER.

By Major J. P. MORGAN, R.A., Assistant Superintendent, Royal Gunpowder Factory, Waltham Abbey.

"Journal of the Royal United Service Institution."

I HAD the honor of being asked last year by the Council of this Institution, to give a lecture on "pebble-powder;" but the subject—which is a very difficult and complicated one—at that time not appearing to me to have been thoroughly worked out in all its details, I begged to be allowed another year for further consideration. I may not even now be able to give a completely satisfactory solution of the whole question, but I hope to bring forward a good many facts connected with the manufacture of pebble-powder, and thus give a tolerably fair idea of the state of matters up to the present time.

The points to be attained, as is well known, in any improvements in the manufacture of powders, are an increased velocity of projectile, a diminished strain on the gun, and greater uniformity of results. It was the introduction of heavy and rifled guns, that drew attention to the importance of these points, and we accordingly find that as the size and precision of fire of guns have increased, the necessity for improved gun-powder has been felt in all countries. In a paper read here in 1871,* I entered very fully into the methods which have been used for determining the explosive force of gunpowder, showing that it is to Captain Rodman, of the United States Army, that we are indebted for having first taught us how the pressure of gunpowder may be measured in the bore of the gun in which it is fired. This is the only satisfactory way of solving the question, and we accordingly find that his experiments led to the discovery that the means of moderating the rate of combustion of gunpowder lay not only in increasing the size of the grain, but also in increasing the density. Thus originated the American mammoth and perforated cake powders, which have since found their way in modified forms into all countries where the art of powder-making has advanced. The prismatic powder, which has been adopted in Russia and Prussia, is derived from the American perforated cake, and the mammoth powder has appeared in Belgium as "*Poudre á gros grain*," and is slowly making its way into France, Italy, and other continental countries. It has been imported into England under the name of "pebble-powder."

As early as 1858, a Special Committee on gunpowder was appointed under the presidency of Colonel Askwith, then Superintendent of the Royal Gunpowder Factory, Waltham Abbey, and their investigations resulted first in the introduction of R. L. G., and afterwards in the recommendation of "pellet-powder" for heavy guns. In their final Report in 1866 they recommended that extensive and systematic experiments should be carried out with the latter powder. They also tried experiments with a pebble-powder which then went by the name of 2 A 4. It was made at Waltham Abbey, in imitation of the American mammoth powder, by breaking up press cake with copper hammers, and sifting the pieces between meshes of 1 and 2 to the inch. The effect of density in modifying the action of powder was overlooked, and this powder when fired in the B. L. guns was found not only to destroy the vent-pieces, but also to enlarge the chambers of the guns, the latter circumstance showing that the fault lay not in the guns but in the gunpowder. It differed from the American mammoth in one very important respect, being only 1.62 instead of 1.82, which is the American density for both cannon and mammoth powders. It is unfortunate that further experiments were not tried with higher densities, as it is probable that thus we should have had our pebble-powder much sooner than has been the case. The importance of density, however, was not at that time so well understood as it now is, and there appears to have been

* On "The Determination of the Explosive Force of Gunpowder," see Journal, vol. xv, page 312 *et seq.*

a bias on the minds of some of the members of the committee in favor of regular grains pressed separately in moulds, which process they considered also could be carried on more economically than the granulation of 2 A 4 powder, where there was a great amount of waste.

The introduction of the mercurial densemeter at a later period allowed the question of density to be more satisfactorily dealt with. This instrument was first designed in France, and was used for some time in tne Chemical Department, Royal Arsenal, before it was introduced in the Royal Gunpowder Factory at Waltham Abbey in 1869.

The present Committee on explosives under the presidency of Colonel Younghusband, Superintendent, Royal Gunpowder Factory, Waltham Abbey, was appointed in 1869, and conducted an extensive series of experiments with various powders by methods similar to those used by Rodman, which led them to the conclusion that pebble-powder was better suited to the requirements of the service than pellet-powder. As it is also now very much easier and safer to manufacture, the change they recommended from pellet to pebble is not to be regretted. It is to the slow and steady progress in the manufacture of this powder that I propose to direct your attention this evening. In doing so, it seems to me that I shall be best able to acquaint you with the subject by giving a short historical sketch of the process as carried out at Waltham Abbey, and, as far as I know, by those merchants who have supplied pebble-powder under contract. You may depend upon the facts I adduce; but I may caution you against accepting too readily the conclusions I draw, because I know no subject where hasty conclusions are so apt to be overthrown as in the case with the manufacture of pebble-powder.

The first specification sealed to govern the manufacture was 16/5/70, the density being 1·8, the size of grain between $\frac{3}{8}$ and $\frac{1}{2}$ inch, and when fired in the 8-inch gun the velocity between 1420 and 1480 f.s., and the pressure in no case to exceed 20 tons in the bore of the gun, as indicated by the "Crusher" gauges in use by the Committee. Soon afterwards, however, it was found that there was a difficulty in maintaining the velocity, and the specification was altered as regards density, with a view to meet the requirements of the case, being lowered to 1.765 in August the same year. Some powder had been made having a density of 1.8, but it was kept in reserve, and afterwards mixed with pebble having a lower density, so as to give a mean of 1.765. The manufacture was continued at this density, and as the proof in the 8-inch gun was satisfactory, it was imagined no further difficulty would be experienced.

The method at first adopted of breaking up the press-cake into pebbles was the same as that described for producing the 2 A 4 grains, viz., the use of copper hammers. This is manifestly a very tedious and troublesome process. It is still, however, to be seen in operation at the Wetteren Factory, in Belgium, where the cake is first cut into strips by a sort of guillotine machine, and afterwards broken up in this fashion by means of wooden mallets in a hollow hemispherical bowl, into pebbles.

A system of chopping up the cake by means of copper knives very soon superceded the method of breaking up by hammers at Waltham Abbey. The cake was first cut up into strips by the knives, and these strips were again chopped across into pebbles by the same instrument. It was, of course, a tedious process, but it had the advantage of making little or no waste, and nearly the whole of the press-cake could thus be converted into grain.

A good many experiments were tried with a view to granulate the pebbles in the same way as ordinary powders, but all the attempts were very unpromising, owing to the irregularity of the grains and the great amount of waste. Messrs. Curtis and Harvey, however, produced a large proportion of their pebble-powder supplied by contract in this manner. They only, I believe, however, obtain about 30 per cent of grain from their cake, and though this low percentage does not inconvenience them, inasmuch as they can find other uses for the smaller grains, it would not do at a Government factory, where there is no other use to which they could be applied.

The chopping-knife was in operation for a considerable time, and turned out

the whole of the pebble manufactured at Waltham Abbey from August, 1870, to May, 1871, during which time about 4,000 barrels of 125 lbs. each were manufactured and sent to Purfleet.

One man could thus cut about 150 lbs. a day, so that the granulation of pebble-powder at that time required the continual employment of nearly 20 men for the very small out-turn of about 100 barrels a week.

The following extracts from the proof books will show the nature of the powder manufactured at this time:

Brand of Powder.	Density.	Date of Experiment.	Number of Experiment.	Muzzle Velocity.	Pressures in Tons.		
					A.	B.	C.
15/10/70	1.761	27/10/70	357	1460	17.1	18.1	16.3
14/11/70	1.765	8/12/70	367	1446	18.1	18.0	15.6
31/12/70	1.757	1/2/71	389	1409	15.4	15.4	14.6
21/1/71	1.759	1/2/71	392	1409	12.6	13.1	12.1
3/2/71	1.761	20/3/71	408	1405	14.1	14.2	13.9
25/3/71	1.759	5/4/71	440	1406	15.5	15.0	14.8

It will be observed that there is a steady decrease in the velocity at proof. Some of the velocities are even lower, but these samples give an idea of the general average of the work produced at this time.

Meanwnile experiments were being carried on with a view to turn out pebbles in larger quantities and more economically than by the tedious process of chopping up with knives. My predecessor, the late Captain Smith, R. A., hit upon a plan which was very successful in doing the same sort of work.

This was by making a succession of knives come into operation one after the other, by being arranged longitudinally on the circumference of two long rollers.

The cake was thus very rapidly cut up into strips, but in putting the latter through the second time endways much time was lost, as each strip had to be picked up separately by hand before being put through. He contemplated having a second pair of rollers of the same description as the first, for the strips to pass through, but was unable to devise a method of conveying them from the first to the second pair of rollers, and so his plan for a time remained in abeyance.

Colonel Younghusband thought that the strips could be conveyed, as they passed the first pair of rollers, in succession to a second pair, which had the knives arranged circumferentially instead of longitudinally.

He found, however, that the strips would not drop horizontally on to the second pair of rollers, but that they dropped as often endways as sideways, and generally that they fell in all directions, owing to the uneveness of the press cake from which they were cut.

Mr. Pigou, of Pigou and Wilks, designed a very ingenious pair of rollers, which performed the work of cutting up the cake into pebbles in one operation. Both rollers were identical and had the knives arranged, longitudinally nor circumferentially, but spirally, at an angle of 45° round the surface. The knives thus crossed each other perpendicularly at the cutting points, and very tolerable granulation was effected. The pebbles, however, were very irregular in shape, and by no means so cubical as those cut up by knives.

It had hitherto been supposed that, the more uniform the size and shape of the grain, the better would be the results at proof; but while Waltham Abbey pebble seemed to be failing at proof, Mr. Pigou's pebble gave very good results, as shown by the following experiment:

Powder.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
Lot 826.....	1.765	28/3/71	428	1460	16.5	16.4	15.8

I have stated my intention of describing the manufacture of pebble-powder as I have learned it myself, and I may here say that this was the position of affairs when I was appointed Assistant Superintendent in succession to Captain Smith. I hope I have succeeded in convincing you that the manufacture of pebble-powder is a great mystery; at least so it appeared to me.

It seemed a tolerably easy matter to turn out powder, but to make it produce the desired results in the 8-inch gun, so as to pass the specification, was quite another affair.

I suggested to Colonel Younghusband that it seemed very probable that the fact that Mr. Pigou's sample consisted of irregularly shaped grains was the reason why he obtained a better velocity than could be obtained with the Waltham Abbey regular cubes, because the irregularly shaped grains would present larger surfaces for initial ignition. It would not do to use small grains, because they would interfere with the passage of the flame in igniting the charge; but there could be no objection to large irregularly shaped grains. Colonel Younghusband tried the experiment, and used the larger rollers in an ordinary granulating machine to break up press cake into irregular grains. This was mixed with knife-cut pebbles, and, on firing a sample of the ordinary work in comparison, the following result was obtained:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
25/4/71	1.770	2/5/71	483	1399	16.9	16.6	15.6
25/4/71 Granl. P.	—	2/5/71	485	1436	19.4	19.3	19.7

It seemed to me that, in Colonel Younghusband's machine, the strips might be made to rectify themselves by being allowed, in the first instance, to drop on a canvas band, which, as it traveled, would convey each strip forward so as to allow the next to drop behind it, and afterwards convey the strips in succession in the proper position to pass through the second pair of rollers.

This plan was tried, and was found to answer quite successfully. A very simple machine thus constructed was in operation from the end of May, 1871, to March, 1872. The following is the proof of the first sample turned out by this machine:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
19/5/71	1.768	24/5/71	534	1475	20.9	20.3	20.0

It will be seen that the velocity and pressure are both high, which is no doubt due to the fact that the pebbles turned out by this machine were smaller than the hand-cut pebbles. The results obtained, however, seem to meet the requirements of the case, especially as the out-turn of the machine was only about 40 barrels a day. The capabilities of the factory in the other processes of manufacture are much greater, and so the chopping process was continued, and the pebbles produced by both processes were mixed together and the total out-turn increased from about 100 barrels to nearly 300 a week.

Colonel Younghusband tried an experiment to compare directly the work produced by hand-cut and machine-cut pebbles, not only with the ordinary work of the factory, but also with work which had been milled with an increased amount of moisture in the charges, with the following results:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
OK. 2/6/71	1.768	10/6/71	549	1440	19.4	19.8	18.6
HK. 2/6/71	1.782	10/6/71	550	1444	16.7	15.6	16.3
OM. 7/6/71	1.787	16/6/71	570	1445	19.7	17.4	16.6
HM. 7/6/71	1.782	16/6/71	579	1437	19.6	18.8	18.0

It will be seen that there is not very much choice, but that on the whole the charges worked "heavy," or with the increased percentage of moisture, produce the best results. The more moisture in the powder the less is the danger arising from an explosion in the mills, and the charges were accordingly afterwards worked heavy. All stovings are proved in the 8-inch gun, and those which meet the required tests are at once "branded," and passed into the service.

The others are mixed in a manner calculated to produce the required results. The velocities and pressures obtained at proof were always a matter of considerable uncertainty. I may compare our various stovings to different vintages of wine. We had an uncertain control over our stovings, but after proof we were able within certain limits to produce any brand required.

A regular systematic mixing had to be established so as to work off and send away the manufactured powder as speedily as possible after proof. At first the stovings were mixed, in a rough and ready way, by two men each taking a barrel and alternately pouring a small portion of the contents into another barrel, but very soon a more methodical and satisfactory plan was established.

It appeared to me that, in order that our mixing should be a success, some plan must be adopted of securing that each stoving itself should be perfectly uniform. It appeared vain to attempt to work to densities, for, from the samples already given, it will be seen that density taken alone is no criterion of what may be expected at proof. A mechanical system of mixing seemed to promise the best results, and this plan was adopted. In order to do this with as little trouble as possible, advantage was taken of some of the processes of manufacture.

A glazing as a rule consists of four large barrels or churns, each of which contains about four small barrels of powder. As these churns revolve at 37 revolutions a minute for four hours, it may safely, I think, be assumed that the contents of each churn are well and uniformly mixed. It by no means follows, however, that the contents of one churn are of the same character as those of the others.

The next process is the stoving, and advantage is taken of the method of setting the stove to make the whole of one glazing perfectly uniform. The powder is set in trays, each tray containing four bowlfuls, or about 16 lbs. In filling a tray, a bowlful is taken from each churn, and thus every tray of a glazing contains exactly the same powder. The glazings are marked off separately in the stove. After stoving, the powder is finished by being revolved about 20 minutes in reels which contain four barrels each, and, as the stove contains four glazings, this gives the required facility for making the whole contents of a stove uniform, because into each reel can be put one barrel from each glazing. I know no process which has been attended with greater certainty in producing uniform powder than this system of mechanical mixing. It gives no extra work, and requires only a little care and attention on the part of the workmen.

Though each stoving, however, is perfectly uniform, it will be seen by the following proofs that different stovings are by no means of the same character. These stovings are selected as giving as near as possible an average of the work turned out, some being higher and some lower as regards velocities and pressures.

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
26/6/71	1.772	14/7/71	648	1461	21.4	21.6	19.4
30/6/71	1.792	5/7/71	627	1332	11.5	11.1	21 0
10/7/71	1.792	14/8/71	59	1385	14.4	14.2	13.8
29/7/71	1.763	7/8/71	38	1507	22.8	20.7	20.0
9/8/71	1.758	18/8/71	80	1400	14.6	15.0	14.4
18/8/71	1.776	25/8/71	101	1442	17.8	17.5	16.6
28/8/71	1.777	6/9/71	134	1408	16.3	16.2	15.0
1/9/71	1.784	6/9/71	137	1358	13.3	13 4	13.4
26/9/71	1.762	9/10/71	225	1436	18.4	18.3	17.1
3/10/71	1.753	13/10/71	253	1440	17 2	17.2	16 7
18/10/71	1.765	27/10/71	298	1438	18.5	19.2	17.1
1/11/71	1.768	9/11/71	336	1428	16.1	16.3	16.4
13/11/71	1.736	23/11/71	375	1469	17.4	18.4	17.8
16/11/71	1.735	23/11/71	377	1512	19.9	21.2	21.0
17/11/71	1.736	23/11/71	378	1534	25.1	24.9	23.5
17/12/71	1.750	15/12/71	459	1438	14.8	16.2	16.1
15/12/71	1.750	2/1/72	501	1396	13.3	12 3	12.8
28/12/71	1.755	3/1/72	524	1391	15.1	14.3	14.4

It will be observed that, though a good many of these stovings are within the limits of the specification, some are very much too low in velocity, while others are too high, both as regards velocity and pressure. Those stovings which were too high in velocity or pressure were mixed with others which were of low velocity and pressure, so as to give a mean result within the specification. This was attended with little inconvenience, as long as the mean results of proof fell within the specification, but it was rather troublesome when there was a long series of proofs of the same character. Some of the proofs, it will be observed, are either exceptionally high or exceptionally low. With regard to stoving, 30/6/71, I find the following note in the proof-book, in Colonel Younghusband's handwriting: — "1,000 grs. sample of this powder was dried by Mr. Abel for five hours, at 200° Fah., resulting in a loss of 0·33 per cent., proving that the very low velocity was not caused by moisture."

Stovings 16 and 17/11/71 call for special remark. Every inquiry was made as to the possible cause of the low densities and high pressures and velocities, but nothing could be traced, excepting that the chief foreman believed that the charcoal had been overburnt. As this fact at the time was thought calculated to produce the opposite effect, the real cause appeared to be a mystery.

The change from the old to the new gun does not appear to make much difference, as it will be observed that there are low velocities with the new as well as with the old. This latter point was not, however, left purely to speculation, for Colonel Younghusband tried identical samples in both guns, with the following results:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
26/6/71	1.772	14/7/71	647	1460	21.5	20.6	18.5
Ditto	Ditto	Ditto	648	1461	21.4	21.0	19.4
5/7/71	1.789	12/7/71	638	1368	13.6	13.5	13.0
Mean of above mixed, 2 to 1	....	....	...	1436	18.8	18.4	17.0
Ditto, 2 to 1 in old gun	....	14/7/71	650	1420	18.9	17.6	16.5
			652	1450	19.5	19.5	18.1
			653	1454	20.4	19.8	18.7
Ditto, 2 to 1 in new gun	...	31/7/71	7	1439	17.6	17.2	16.3
			8	1453	18.7	18.9	17.5
			9	1449	19.8	19.8	18.1

The plan of mixing the stovings, as I have stated, was at first by hand, but toward the end of 1871, a four-way hopper was made, which materially assisted this process. Sometimes the stovings were mixed two and two, and sometimes four and four, according to the circumstances of the case.

I have brought the manufacture at Waltham Abbey, down to the end of 1871, and it will be observed that the old tendency to low velocity again begins to manifest itself; and, as this tendency appeared on the whole rather to get worse than better, it began to become troublesome. Not only at Waltham Abbey did it show itself, but in nearly all the powder sent in by the merchants by contract. Lot after lot manufactured by Messrs. Curtis and Harvey, and by the Kames Company especially, showed the same failing; and the question of the manufacture of pebble began to look serious.

The new year, however, introduced a new era. A sudden fit of inspiration seized Colonel Younghusband, and he ordered two samples to be restoved. Behold the result:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
10/1/72	1.765	24/17/2	605	1398	15.8	15.5	14.8
Ditto re-dried	....	31/17/2	677	1455	20.9	20.3	18.5
12/1/72	1.763	24/17/2	606	1367	13.8	13.8	13.8
Ditto re-dried	....	31/17/2	678	1418	15.6	13 6	14.6

It was a great relief to have discovered the reason at last. Doubtless some will think it was very foolish not to have discovered it sooner; but I hope they will suspend their judgment till they have heard the whole state of the case. Meanwhile I will observe that the cause had been suspected, and, as I have stated, a sample sent to the Chemical Department for analysis, showed a very small loss of moisture. The powder had received the usual amount of stoving. But, what is of more importance is, that when the discovery was communicated to the merchants, with a view to assist them out of their difficulties, one and all refused to believe it.

At Kames an experimeat was made to test the matter roughly, by weighing a large sample before re-stoving, and weighing it again afterwards, and, as only a slight difference of weight was detected, it was concluded that the fault of Kames' powder did not lie in its insufficient drying. An experiment was afterwards made at Waltham Abbey, with some of Kames' pebble, which partly bears out the result. Two samples were re-stoved, and fired as follows:

Brand of Powder.	Density.	Moisture.	Experiment.		M. V.	Pressure.		
			Date.	No.		A.	B.	C.
Lot 86.....	1.772	1.17	21/5/72	964	1338	16.1	16.1	14.8
Ditto, re-dried.	.....	.898	7/6/72	1030	1394	19.3	17.6	17.0
Lot 97	1.755	1.14	21/5/72	968	1336	16.2	16.4	15.0
Ditto, re-dried.	.....	.816	7/6/72	1031	1379	18.2	18.5	15.8

It will be observed that in the original samples there is no excessive amount of moisture, but rather under the normal amount if anything, and the re-dried samples may be considered over-dried.

The discovery of the great effect of moisture on velocity and pressure opened up a very large question, and threw discredit to some extent on all the experiments which had hitherto been made,

seeing that it could not be told to what extent all the results had been vitiated by an unknown amount of moisture which existed in the samples fired. It at once explained why there had been so much low velocity powder a year before, and there can be no doubt that, had the reason been known in time, it would have been better to have re-dried some of the powder which had been mixed.

The manufacture continued as before, with varying results; sometimes the proofs were right, and sometimes they were too low, in which case they were re-dried, or mixed with others that were too high.

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
8/2/72	1.756	15/2/72	710	1427	18.8	17.5	16.5
21/2/72	1.754	29/2/72	739	1478	17.9	18.2	17.3
4/3/72	1.762	7/3/72	778	1389	16.4	15.6	15.8
Ditto, re-dried	....	13/3/72	...	1466	18.1	18.6	18.0
23/3/72	1.762	8/4/72	900	1430	20.3	19.1	17.8

The last sample, it will be observed, shows a falling off in the powder, and the reason is to be explained as follows. A new machine on Colonel Younghusband's principle had been made, and had just then come into operation. It turned out such a large quantity of pebble that we could now dispense with the more expensive process of cutting by knives. The machine was calculated to give pebbles as large as with the knives, but evidently there was a fault somewhere. On examination I found that there were a great number oi flakey pebbles, of the description of cubes, divided down the middle. They thus were in length and breadth of the proper dimensions, but in thickness only half of what they ought to be. This I considered to be due to the faulty principle of the second pair of rollers, which did not allow of the strips extending outwards, as they were being cut. Though they were very detrimental to the proof of the powder. they could not be removed by the ordinary method of sifting. I succeeded in removing them, however, by the device of an oblong mesh.

When being sifted, the flakey pebbles tilted on their edges, and passed through while the ordinary pebbles were retained. It was found that the system of re-drying was rather troublesome, as it occupied the stoves frequently, when new powder was required to be dried; and, as 36 hours' drying could be given without extra inconvenience, the time of drying was increased on 1st April, 1872, to 36 hours, at the old temperature of 125° Fah. The following are some of the proofs:

Stoving.	Density.	Experiment.		M. V.	Pressures.		
		Date.	No.		A.	B.	C.
12/4/72	1.756	19/4/72	815	1428	17.6	18.2	16.3
22/4/72	1.752	26/4/72	923	1455	21.8	21.8	19.6
10/5/72	1.772	17/5/72	937	1408	15.2	15.3	14.8
Ditto, re-dried	....	29/5/72	1002	1507	21.6	21.2	17.7
13/5/72	1.777	17/5/72	940	1452	15.3	14.9	14.1

The last shows a considerable improvement over the others, being due to a great extent to the fact that a sifting apparatus, of the nature described, was now erected on the machine, so as to sift the pebbles rather severely, by taking out all the small and flakey specimens. This materially reduced the percentage of finished pebbles obtained from it; that, however, is not to be con-

sidered in comparison to the improvement produced in the powder.

I had all along been favorable to the principle of the other machine, proposed by Captain Smith, and had for some time, after a good deal of trouble and contrivance, got a design ready, by which the strips could be conveyed from the first to the second pair of rollers. When Colonel Younghusband found, therefore, that the percentage of pebbles produced with his machine was only about 60 per cent., I obtained his permission to have an experimental machine made according to my design..

It will be observed that the difficulty consists in conveying the strips, which fall in regular succession, from the first to the second pair of rollers, so that they not only shall not inconvenience each other, but also shall change their direction from moving sideways to a motion endways. This I accomplished by allowing the strips to fall upon a board, over which a succession of strips of wood were moving sideways, and scraping along the surface. Each strip fell into a space between two strips of wood, and was carried sideways along the board. When the first strip got to the end of the board, it dropped over on to a band passing below in a direction at right angles, and was thus conveyed endways to the second pair of rollers. It is manifest, if the board remained stationary, the second strip would drop over on to the top of the first before it had time to clear out of the way. To prevent this the board was made to move backwards so that the second strip, instead of falling on the top of the first, fell along side it, and slightly in arrear, and so on with the next and the next, till the board had moved as far back as could be allowed. The direction of the board was then suddenly changed and it moved forward in the direction of the strips of wood and at the same rate, so as to form a false bottom to the compartments which contained the strips of powder. When the board had arrived again at the original position, it again suddenly changed its direction and the motion proceeded as before. The method of changing the direction of the board was by attaching it to an endless chain which passed over two smal pulleys. Thus the direction was reversed every time of passing over a pulley.

It will be observed in the last samples of firing given, that the density has increased. Of course it was at once apparent, if the fault of low velocity was due to the moisture, there was no need to attempt to meet the case by working to the low limits of density, and the density was therefore increased. It was found, too, that even 36 hours' drying at 125° F. was not sufficient, and on the 1st June the temperature of the stove was increased to 135° F., for 36 hours, with the following result. The moistures are given at the same time to serve as a guide, if possible, to what may be expected at proof :

Stoving.	Density.	Moisture.	No. of Pebbles to 1 lb.	Experiment.		M. V.	Pressures.		
				Date.	No.		A.	B.	C.
4/6/72	1.781	—	—	12/6/72	1034	1450	16.4	16.8	16 0
1/7/72	1.780	—	—	12/7/72	1109	1465	18.2	18.9	17.9
6/8/72	1.784	.93	—	15/8/72	1200	1447	17.5	19.2	16.8
21/8/72	1.781	1.03	—	13/9/72	2	1493	20.8	19.8	18.0
2/9/72	1.779	.9	—	4/10/72	37	1494	19.7	18.7	17.1
3/9/72	—	—	—	4/10/72	39	1492	17.1	15.9	16.4
1/10/72	1.777	1.44	80	9/10/72	63	1491	18.3	17.4	17.1
4/11/72	1.782	1.38	80	8/11/72	110	1452	16 4	16.4	16.1
22/11/72	1.781	1.57	70	2/12/75	143	1494	18.5	18.8	18.0
4/12/72	1.779	1.34	72	13/12/72	170	1475	18.6	16.2	16.9
14/12/72	1.772	1.33	76	24/12/72	187	1541	19.7	19.1	19.4

I have brought down the manufacture to the end of 1872, and I think it will be admitted that there is considerable improvement on the state of matters which obtained a year before. Not only has the velocity been very much increased,

but the pressures have been very considerably reduced. This latter point is mainly due to the increase in the size of the pebbles. Instead of being about 140 to a pound, they are now between 70 and 80, as shown by the column of figures. It will be observed that, with the introduction of a new proof gun, there is a considerable rise in the average velocity. This is, no doubt, due to the fact that the old gun had fallen off to some extent by the wear of the bore. It is not possible exactly to say how much, but evidently it is some 30 or 40 feet in 1,200 rounds. Stoving 3/9/72 is the first sample with the machine I have described as worked out by myself on Captain Smith's principle. It not only gave much better pebbles, but a much larger percentage—about 80 per cent. This machine has ever since continued in constant operation without mishap, and has done the greatest amount of the work of granulation or pebble-cutting. The sifting arrangement in use with Colonel Younghusband's machine was an ordinary shaking screen, but it was found that the mesh for taking out the small and flakey pebbles was apt to choke up and interfere with its proper action. One of the foremen of the Machinery Department suggested that a reel would be more suitable. This was applied to my machine with the oblong mesh described, and has been found to work very satisfactorily. A reel of the same sort is now being fitted to Colonel Younghusband's machine.

[TO BE CONTINUED.]

THE CHEMICAL CHANGES ACCOMPANYING THE SMELTING OF IRON IN BLAST FURNACES.

By Dr. C. R. ALDER-WRIGHT, F.C.A.

Proceedings before the Royal Institution.

NOTWITHSTANDING that the operation of iron-smelting is one dating from a very early epoch, and in spite of its magnitude at the present day, and the consequently numerous series of observations and experiments made thereon by various chemists, it is nevertheless true that until recently our knowledge of the chemical changes which occur during the process was extremely limited.

It will not be necessary for me to-night to enter into any detailed description of the apparatus and machinery now in use in this manufacture; the blast furnace, as you are all aware, is virtually a gigantic vertical tube into the top end of which the materials used are continually inserted; these consist of the ore to be smelted, the fuel, and lime or lime-stone as a flux. At the lower end of the tube air usually heated to 300°–500° is continually injected by a blowing engine through nozzles termed *tuyeres*, whereby the fuel is burnt and the necessary heat generated: the earthy materials of the ore and the lime of the flux unite, forming a fusible "slag," which is continually drawn off at the base, whilst the molten reduced iron accumulates below the slag, being specifically heavier, and is drawn off from time to time into moulds of sand, when it constitutes the pig iron of commerce.

Ordinarily the air injected, or "blast," is previously heated by passing through tubes of iron or piles of brickwork, themselves heated by the combustion of the waste gases that escape from the furnace itself; to collect these, the top of the furnace is closed by a bell-shaped valve which serves for the introduction of materials when open, but which when closed compels the gases to issue through an orifice in the side of the furnace near the top, whence they are led away through pipes to the heating stoves, furnaces of boilers, &c.

The nature of the ore used necessarily exerts a great influence on the chemical changes that take place; the following Table indicates the general composition of several of the chief descriptions of ore used. In some instances the iron exists naturally as ferric oxide; in other cases chiefly as ferrous carbonate.

	Hæmatite.	Magnetic Ore.	Spathic Ore.	Clay Ironstone.	Brown Ore.
Fe_2O_3	90–100	30–70	0–3	0–3	40–70
FeO	....	13–33	36–50	35–55	0–5
Al_2O_3	0–2	0–5	0–2	1–7	1–7
CaO	0–3	0–5	0–4	1–14	1–7
MgO	0–1	0–2	0–4	1–9	0–2
MnO	0–1	0–1	1–25	0–2	0–3
SiO_2	0–10	0–10	0–5	2–17	1–35
CO_2	0–1	0–10	37–42	22–37	0–5
P_2O_5	0–1	0–2	trace	0–2	0–2
SO_3	0–1	trace	"	0–3	trace
H_2O	0–1	0–4	...	0–1	6–18
Essential Composition	Fe_2O_3 with little or no earthy matter.	Fe_2O and FeO with earthy matters.	$FeCO_3$ and $MnCo_3$ crystalline.	$FeCO_3$ and much earthy matter.	Hydrated Fe_2O_3 and earthy matters.

When ferrous carbonite constitutes the ore used, the smelting process is usually facilitated by submitting it to a previous calcination in a kiln like a lime-kiln, whereby the ferrous carbonite becomes transformed into ferric oxide; when, however, the carbonate is not calcined before use, it speedily loses the carbon dioxide present therein, leaving behind an oxide of iron; this occurs in the top portion of the furnace, so that virtually the ores used may be regarded as consisting essentially of some form of iron oxide, with a varying amount of earthy matter, of variable kind intermixd therewith.

The fuel used is ordinary coke or charcoal; when, however, raw coal is employed, it is completely coked in the top portion of the furnace, so that the fuel burnt at the tuyeres is invariably carbon.

As the blast enters the furnace it comes in contact with a mass of incandescent carbon, whereby its oxygen is firstly converted into carbon dioxide, and nextly into carbon oxide, the nitrogen for the most part remaining unchanged; not impossibly, a good deal of the carbon is burnt directly to carbon oxide, without passing through the intermediate stage of carbon dioxide; any moisture present in the blast is similarly converted into a mixture of carbon oxide and hydrogen; the amount of the latter necessarily varies with the hygrometric state of the atmosphere. Although hydrogen is a powerful reducing agent, the influence of the small quantity present in the blast-furnace gases appears to be practically *nil:* the gases issuing at the top of the furnace contain on an average about as much free hydrogen as is brought in by the blast, whence it is evident that the hydrogen has contributed little or nothing to the reduction of the ferric oxide; and again, practical experience shows that the more moisture enters the furnace at the base, the more fuel is requisite to do the work, *i. e.* the development of hydrogen is injurious to the action rather than auxiliary.

What I shall have the honor of bringing before you to-night is the history of the changes that occur as the mixture of carbon oxide and nitrogen formed in the vicinity of the tuyeres rises through the furnace. This action has usually been described hitherto as a very simple one; the carbon oxide being viewed as simply removing the oxygen from the higher oxide of iron, forming successively a lower oxide and metal, carbon dioxide being evolved in accordance with equations (1) and (2), *infra.*

TABLE of CHEMICAL CHANGES taking place in different parts of the BLAST FURNACE.

[A] Reduction of higher oxide to lower oxide and metal by gaseous carbon oxide.

(1) $Fe_xO_y + CO = Fe_xO_{y-1} + CO_2$
(2) $Fe_xO_y + yCO = x\,Fe + yCO_2$

[B] Oxidation of metal to lower oxide and higher oxide by carbon dioxide.

(3) $x\,Fe + yCO_2 = Fe_xO_y + yCO$
(4) $Fe_xO_{y-1} + CO_2 = Fe_xO_y + CO$

[C] Reduction of carbon oxide to carbon.

(5) $x\,Fe + yCO = Fe_xO_y + yC$
(6) $Fe_xO_{y-1} + CO = Fe_xO_y + C$

[D] Reaction of reduced carbon on iron oxide forming carbon dioxide.

(7) $2\,Fe_xO_y + C = CO_2 + 2\,Fe_xO_{y-}$
(8) $2\,Fe_xO_y + yC = yCO_2 + 2x\,Fe$

[E] Reaction of carbon dioxide on reduced carbon.

(9) $CO_2 + C = 2\,CO$

The changes that really take place are, however, much more complicated; it is true that these reactions do take place, but firstly carbon dioxide has a tendency to act on metallic iron, re-forming an oxide, and re-producing carbon oxide by reactions that are just the converse of (1) and (2), *viz.* in virtue of equations (3) and (4).

Nextly, metallic iron acts on carbon oxide, setting free carbon and forming successively a lower and a higher oxide in virtue of equations (5) and (6).

Again, the carbon deposited in virtue of reactions [C] reacts on the higher oxides of iron, producing lower oxides and metal, with evolution of carbon dioxide, in accordance with equation (7) and (8). And finally, carbon dioxide reacts on the deposited carbon, giving rise to the formation of two proportions of carbon oxide in virtue of equation (9).

Changes [A] and [D] may be referred to as *iron-reducing*, [B] and [C] as *iron-oxidizing:* changes [C] may be termed *carbon-reducing*, [D] and [E] *carbon-oxidizing.*

At any given point in the blast furnace all these chemical tendencies are at work simultaneously with more or less vigor according to circumstances; the action actually taking place at this point is, therefore, that due to the single resultant of all the multifarious forces at work; before, therefore, it is possible to enter into any explanation of the chemical changes occurring in the furnace it self, some knowledge must be gained of the relative magnitudes of these several forces. Considerable additions to our knowledge on these points have recently accrued, chiefly through the labors of I. Lowthian Bell, Esq., M.P., with whom I had the pleasure of co-operating in his researches.

As regards tendencies [A]. Although carbon oxide exerts no action on ferric oxide at ordinary temperatures, yet its influence is appreciable at temperatures far below the limit of the mercureal thermometer; the precise point at which the action commences varies with the physical condition of the ferric oxide; thus the following Table illustrates this point:

TEMPERATURE at which CARBON OXIDE begins to reduce FERRIC OXIDE.

Substance.	Minimum Temperature at which Carbon Dioxide is formed.	Temperature at which action is well marked.
	°	°
Precipitated by ammonia	141	149
Calcination of ferric nitrate	145	154
Average calcined Cleveland ironstone	199	210
Ditto, more highly calcined	200	206
Calcination of ferrous sulphate	208	216
Pumice-stone soaked in ferrous sulphate solution and calcined	211	227

The fact that the action is perceptible at so low a temperature may be conveniently illustrated by passing a current of pure carbon oxide over precipitated ferric oxide in a flask heated to 150° in a paraffin bath, and passing the gases subsequently through baryta water, when the formation of a turbidity denotes the production of carbon dioxide. (*Experiment performed.*)

It is noticeable that a specimen of ferric oxide that has been already slightly reduced in this way is first acted upon only at a higher temperature than that required in the first instance.

As regards equation (2.) it may be remarked that it is impracticable to reduce *the whole* of any sample of iron oxide by means of gaseous carbon oxide at any temperature short of a white heat; in fact, metallic iron decomposes carbon oxide, becoming itself more or less oxidized at all temperatures below this in virtue of equation (5).

In reference to the converse changes [B], the oxidizing effect of carbon dioxide on iron is scarcely appreciable at a temperature of 300°, but it is noticeable at 400° and upwards, being very considerable at about 600°: this may be illustrated by passing a current of carbon dioxide over fragments of metallic iron in a tube heated to a bright red heat, when much carbon oxide is evolved, so

that the issuing gases may be inflamed. (*Experiment performed.*)

The physical condition of the iron employed necessarily exerts a considerable influence on the rapidity of the reaction, the more finely divided the metal, the more energetic being the action; thus pyrophoric iron is readily acted on by the air at the ordinary temperature, whilst more massive fragments of metal are unaffected under the same circumstances.

It is noteworthy that carbon dioxide is not capable of acting on all metals alike in this way. Copper, for instance, is unaffected at a red heat or upwards by carbon dioxide, whilst nickel and cobalt are oxidized with the production of carbon oxide, the change, however, taking place with less ease than with pure iron. The following Table illustrates this point.

COMPARATIVE ACTION of CARBON DIOXIDE on IRON, NICKEL, and COBALT, at about 600°.

Iron	100
Cobalt	44
Nickel	11

Iron first begins to act	below 420°
Cobalt " "	about 550°
Nickel " "	above 550°

The consideration of the causes that lead to the possibility of the occurrence of the inverse reactions [A] and [B], and the different behavior of iron and copper towards carbon dioxide, introduce us to some general principles in chemical dynamics. Whenever a body unites with oxygen, heat is evolved; thus the following Table illustrates the quantity of heat produced by the union of 16 parts by weight of oxygen with various substances, the materials and products being all viewed as being examined at the constant temperature 500° C.

The numbers are calculated from the so-called "heats of combustion" of the bodies (at 15°) by means of the formula.

$$H_{500} = H_{15} + h_1 + h_2 - h_3,$$

where H_{500} = the heat of combustion at 500°.
H_{15} = " " " 15°.
h_1 = the heat required to raise the combustible from 15° to 500°.
h_2 = the heat required to raise the oxygen through the same range.
h_3 = the heat required to raise the product of combustion through the same range.

Combustible.	Product of Combustion.	Kilogramme heat units evolved at 500°.
Iron	Magnetic (and probably any other) oxide*	66.7
Carbon oxide	Carbon dioxide	68.8
Carbon	Carbon oxide	27.4
Carbon	Carbon dioxide	48.1
Hydrogen	Steam	58.9
Copper {	Cuprous } oxide*	37.6
Copper {	Cupric } oxide*	37.6

The evolution of heat during these actions may be exemplified by sprinkling iron filings into a large gas-blowpipe flame, when a brilliant shower of sparks is produced, heat and consequently light being developed by the oxidation of the iron. (*Experiment performed.*) Similarly by burning carbon oxide at a jet through which a stream of oxygen can be forced, a blowpipe flame is produced equal in heating power to the oxy-hydrogen flame, and like it capable of igniting lime, and thereby giving off a bright light, melting platinum, steel, &c., &c. (*Experiment performed.*) Although carbon oxide actually gives out more heat than hydrogen in uniting with a given weight of oxygen (68.8 kilogramme units as against 58.9 when the action takes place at 500°), it is nevertheless much more difficult to obtain the same calarofic effects from a carbon oxide-oxygen flame than from an oxydydrogen flame. With a small flame, platinum may be readily fused and lime heated to intense brilliancy with either; but the

* When a body forms more than one *solid* oxide corresponding to a class of stable well-defined salts, the heat produced for a given weight of oxygen consumed is identical with each oxide; this is not the case when *gaseous* oxides are formed as with carbon; nor even when solid oxides are formed when they do not correspond to classes of stable well-defined salts, *e.g.* some of the oxides of manganese.

latter gives a much more compact, and therefore hotter, flame when larger amounts of gas are used: the comparative slowness with which the carbon oxide oxidizes is illustrated by the circumstances that a jet of this gas issuing under some slight pressure from a narrow orifice will not continue to burn in the air, the flame as it were blowing itself out; whilst a jet of hydrogen or of coal-gas burns readily under the same circumstances.

It seems to be a general rule that no reaction of replacement coming under the general form

$$x + yz = y + xz$$

can take place if the reaction is attended with any considerable absorption of heat; *i.e.* the heat given out by the substances x and y, in uniting with the same weight of z, must either be approximately equal, or else that given out by x in uniting with z must be greater than that evolved by y in combining with z. Some few exceptions to this rule are known, notably reactions [D] and [E]: generally, however, the converse is the case, *i. e.* in reactions of this class there is usually an evolution of heat.

Now copper and carbon oxide are not thermally equal as regards combination with oxygen; the latter evolves nearly double the heat given out by the former in uniting with a given weight of oxygen: hence the action of carbon oxide on copper oxide, producing metallic copper and carbon dioxide, must be attended with a large evolution of heat; thus at 500°:—

Heat produced by oxidation of carbon oxide to dioxide	+ 68.8
Heat absorbed during the reduction of copper oxide	— 37.6
Heat evolved	+ 31.2

Carbon oxide, therefore, reduces copper oxide to metal, forming carbon dioxide in accordance with the above rule; whilst the converse reaction, *viz* oxydation of metallic copper by carbon dioxide and conversion of the latter into carbon oxide, does not take place, as it would be attented with a large absorption of heat *viz.* 31.2 kilogramme units.

The evolution of heat during the reaction of carbon oxide on copper oxide, may be readily illustrated thus:—A tube filled with lumps of copper oxide is heated to a temperature short of visible redness, and a stream of carbon oxide is passed through it; the copper oxide immediately begins to glow brightly from the heat evolution that ensues during the reduction of the metallic oxide: on leading oxygen through the tube, when the reduction is over, and the mass has cooled down so as to be no longer visibly red hot, a still brighter glow is produced from the heat evolution during the reoxidation of the metal: the glowing is less bright in the first instance for the threefold reason that there is somewhat less heat evolved (31.2 units as against 37.6), whilst the resulting carbon dioxide escapes while very hot, and consequently removes heat; again it dilutes the carbon oxide and makes its action less energetic. (*Experiments performed.*)

In reference to the general rule just referred to relating to the connection between the heat evolution on combination and the relative action of bodies on one another, one particular case is noteworthy, of which reactions [A] and [B] afford a good example: if in a reaction of the form

$$x + yz = y + xz$$

there is little or no evolution of heat (*i. e.* if x and y both evolve approximately the same amount of heat in uniting with the same weight of z), it often happens that the converse reaction

$$y + xz = xyz$$

may be brought about by modifying the circumstances, so that the following is the general rule for all cases as regards the equation

$$x + yz = y + xz.$$

Case (1).—x evolves more heat in uniting with z than y does.

The reaction takes place under suitable conditions.

Case (2).—x and y evolve approximately the same amounts of heat in uniting with z.

The reaction may take place or its converse, according to circumstances.

Case (3).—x evolves considerably less heat than y in uniting with z.

The reaction (usually) does not take place, but the converse reaction fre-

quently can occur under suitable conditions.

Thus in the case of reactions [A] and [B], there is but little heat evolution or absorption in either case.

[A] Heat evolved by oxidation of carbon oxide to dioxide	+ 68.8
Heat absorbed by reduction of iron oxide	— 66.7
Heat evolved	+ 2.1
[B] Heat evolved by oxidation of iron	+ 66.7
Heat absorbed by reduction of carbon dioxide to oxide	— 68.8
Heat absorbed	— 2.1

In this respect reactions [A] and [B] may be compared with another well-known pair of inverse reactions, *viz.* the oxidation of iron by passing steam over it, hydrogen being evolved: and the reduction of iron oxide by passing hydrogen over it, steam being produced. In each of these cases, also, the thermal disturbance is not great, *i.e.* hydrogen and iron are thermally approximately equal in reference to their combination with oxygen at 500°.

STEAM AND IRON.

Heat evolved by oxidation of iron	+ 66.7
Heat absorbed by reduction of steam	— 58.9
Heat evolved	+ 7.8

HYDROGEN AND IRON OXIDE.

Heat evolved by oxidation of hydrogen	+ 58.9
Heat absorbed by reduction of iron oxide	— 66.7
Heat absorbed	— 7.8

From the existence of the inverse reactions [A] and [B] it results that when a mixture of the two oxides of carbon acts either on metallic iron or on iron oxide, oxidation of the one or reduction of the other takes place until a definite relation exists between the iron and oxygen present in the resulting substance and the two oxides of carbon in the gaseous mixture; the composition of the inert substance necessarily varies with the temperature and the nature of the mixture of carbon oxides used; the higher the temperature and the more carbon dioxide is present, the larger is the amount of oxygen present in the inert substance. Thus Bell obtained the following numbers:

CO_2 per 100 volumes of CO.	Temperature.	Oxygen in inert Oxide, Fe_2O_3=100	Carbon deposited per 100 of Fe.
600	Red heat	90.0	nil
100	Bright red heat	67 5	"
47	Full red heat	8.2	"
11	Approaching whiteness	11.9	"
Nil (pure CO)	Bright red heat	1.0	0.3

Reactions [C]. The oxidation of carbon to carbon oxide evolves less heat than the conversion of iron into iron oxide; hence it might be inferred that iron will probably decompose carbon oxide with the evolution of heat, carbon being set free and an oxide of iron formed; thus thermally

Heat evolved by oxidation of iron	+ 66.7
Heat absorbed by reduction of carbon oxide to carbon	— 27.4
Heat evolved	+ 39.3

The circumstances attending this change have been studied at great length by Bell; at temperatures not higher than 200° it is possible to obtain small quantities of deposited carbon in virtue of these reactions; but the action is at a maximum of about 420°–450°; at higher temperatures but little carbon can be obtained in this way, owing to the carbon-removing influences [D] and [E]; a few tenths per cent. of carbon, however, are always deposited, the same result being arrived at whether metallic iron or ferric oxide be employed in the instance. The oxygen communicated to the iron is for the most part removed again in virtue of reactions [A] and [D]; a minute quantity, however, is retained at all temperatures up to about 1000°. Since carbon is also present in the product, it might be supposed that the oxygen is present as oc-

cluded carbon oxide; that this is not the case, however, is shown by the circumstance that the whole of the carbon present is left behind in the free state on dissolving the impregnated iron in iodine water, or copper sulphate solution. Moreover, the oxygen present is, under these circumstances, left behind in the form of an oxide of iron.

The process acieration depends in the first instance on the occurrence of reactions [C]; carbon oxide is absorbed by the bars of iron, and is decomposed, particles of carbon being deposited and iron oxide formed, this latter being immediately reduced again, either by carbon oxide (reactions [A]), or by acting on a part of the deposited carbon (reactions [D]); the blisters on blister steel are probably produced by the attempts at egress of the carbon dioxide thus produced.

When ferric oxide is exposed to the action of carbon oxide at about 420°, the time required to produce a given amount of carbon deposition varies greatly with the physical structure of the iron oxide probably because this physical structure influences, as above described, the rate at which iron and lower oxides are formed in virtue of reactions [A]: thus the following Table indicates the relative amounts of carbon deposited from various kinds of ferric oxide, by similtaneous exposure to the action of carbon oxide at 420°, for seven hours:—

	Carbon deposited per 100 of iron.
Calcined ferric nitrate	144.0
Precipitated by ammonia	95.4
Calcined ferrous sulphate	54.5
Pumice-stone soaked in ferrous sulphate and calcined	14.9
Calcined Cleveland ironstone	0.3

After ten or twelve hours, however, the discrepancy is not so marked, as much carbon being then deposited with the Cleveland ore as it is with the precipitated oxide in seven hours.

The action of carbon oxide on certain other metals and their oxides has also been examined by Bell; the chief results arrived at are included in the following Table:—

COMPARATIVE ACTION at 400°–500° of CARBON OXIDES on various METALS and OXIDES.

Higher oxides of iron, nickel, and cobalt; Reduced to lower oxides, and partially to metal; suboxides (Fe_2O, Ni_2O, and Co_2O) being formed and much carbon deposited.
Spongy metallic iron, nickel, and cobalt; Partially oxidized, much free carbon being formed; iron most active, nickel least.
Higher oxides of manganese; Reduced only to monoxide (MnO); no free carbon being deposited.
Oxides of copper and lead; Reduced to metals; no free carbon deposited.
Oxides of zinc, chromium, and tin; metallic copper, lead, zinc, and tin. No effect.

In each one of these cases, where any action at all ensues, it is uniformly of such a nature as to be included in the general rule above laid down; thus nickel and cobalt give out approximately as much heat in uniting with 16 grammes of oxygen as does iron, and therefore behave in an analogous fashion, giving rise to converse reactions analogous to [A] and [B].

Reactions [D]. The occurrence of these reactions may be readily demonstrated by heating to redness an iron tube containing a mixture of carbon (as free as possible from hydrogen) and ferric oxide. As soon as the temperature rises to about 400°, carbon dioxide is evolved. The reaction, however, is complicated by the circumstance, that the evolved carbon dioxide reacts on both the carbon present and the iron or lower oxides of iron formed by reactions [D], so as to give rise to the production of carbon oxide by reactions [E] and [A] respectively; hence, as the action goes on, the amount of carbon dioxide in the mixture gradually lessens, and finally little but carbon oxide is evolved. (*Experiment performed.*)

It appears exceedingly probable that the so-called "occluded carbon oxide" contained in malleable iron is really not occluded at all, but is produced in virtue of these reactions from a mixture of carbide and oxide of iron; as already stated, on exposing pure metallic iron to the action of pure carbon oxide at a bright red heat, a substance is obtained containing both carbon and oxygen, *not* in the form of occluded carbon oxide. On heating this product, in a Sprengel vacuum, a mixture of carbon dioxide and carbon oxide is evolved (the latter predominating greatly).

The whole process of "puddling" depends on the occurrence of reactions [D]; the carbon present in the iron (to-

gether with other impurities) is thus eliminated by the reaction on it of iron oxides formed in the puddling furnace by the action of the heated air.

Reactions [D] are thermally abnormal; although carbon displaces iron from its oxide, the reaction is attended, not, as might be supposed, with an evolution of heat, but with a considerable absorption; thus at 500°

Heat evolved by oxidation of carbon to carbon dioxide	+ 48.1
Heat absorbed by reduction of iron oxide	— 66.7
Heat absorbed	— 18.6

Reaction [E] is also abnormal, being attended with a still greater absorption of heat: thus at 500°,

Heat evolved by oxidation of carbon to carbon oxide	+ 27.4
Heat absorbed by reduction of carbon dioxide to carbon oxide	— 68.8
Heat absorbed	— 41.4

The physical structure of the carbon used has a considerable influence on the temperature at which both reactions [D] and [E] first take place; the lighter and more porous, the more readily is the carbon acted on; that deposited by reaction [C] is especially easily acted on; with ordinary charcoal or coke, reaction [E] does not appear to take place to any appreciable extent below 400°.

It is noteworthy that in some other cases besides reactions (D] and [E], where *solid* carbon is concerned, abnormal results are found to be produced; thus, by the action of carbon oxide on metallic zinc or tin, carbon should be set free even more readily than by iron, nickel, or cobalt, the oxidation-heat of each of the first two metals (per 16 grammes of oxygen) being greater than that of either of the latter three; in point of fact, however, no change at all ensues.

The gases of the blast furnace contain not merely carbon oxide and carbon dioxide, but also a large bulk of nitrogen; all experience, however, goes to prove that this acts solely as a diluent, and in no way interferes with the above-described reactions, saving in delaying them, *i. e.* causing more time to be required for their performance; the presence of nitrogen is, however, of great importance as regards another set of chemical reactions taking place in the lower portions of the furnace.

It has long been known that when nascent potassium or sodium vapor finds itself simultaneously in contact with carbon and nitrogen, the three elements combine, forming a metallic cyanide; the following experiment illustrates this fact: a small charcoal furnace is fed with charcoal previously soaked in potassium carbonate solution and dried; a strong blast of air is then injected into the lower part of the furnace, all apertures being well closed up with clay; when the temperature attains a high enough degree cyanide of potassium is formed,* and escapes to some extent along with other potassium compounds in the form of white fumes carried up by the escaping gases: by diverting these gases through a lateral tube into a vertical tower filled with flints, the solid fume is to a great extent deposited on the surface of the flints; by pouring water down the tower, the fume is dissolved and a solution of potassium cyanide (*inter alia*) trickles out at the base of the tower: on filtration and testing with ferrous and ferric salts and hydrochloric acid, this liquor gives an abundant prussian-blue reaction, showing the presence of much potassium cyanide. (*Experiment performed.*)

The cyanide thus formed acts on the last portions of unreduced oxide of iron, converting it into metal and becoming itself changed to cyanate; at the high temperature of the furnace near the tuyeres this cyanate is probably decomposed with the formation of an alkaline carbonate, and the elimination of nitrogen: a portion of the alkaline carbonate is again converted into cyanide; the majority, however, escapes, and is carried upwards by the stream of gases, and condenses as a kind of sublimate on the suface of the materials in the upper part of the furnace: considerable quantities of cyanides are also carried up in this way. The alkaline sorts thus condensed in the upper portions of the furnace are again brought down to the level of the

* The production of cyanide on the small scale in this way as a lecture illustration appears to be facilitated by the admixture of oxide of iron with the prepared charcoal, but is not always successful, the cause of failure being unknown.

tuyeres as the materials sink; hence each particle of alkali metal does duty over and over again, the alkalies introduced in small quantities in the fuel, &c., thus accumulating in the furnace to a very large extent. The enormous amounts of upwards of 4 cwt. of alkali metals and 2 cwt. of cyanogen per ton of iron made, have been repeatedly found in the gases near the level of the tuyeres. It appears very probable that the large excess of fuel required during the first few days of starting a new blast furnace is mainly due to the circumstance that cyanides have not formed to any great extent from the necessary want of this accumulation; after a very short time, however, considerable amounts of cyanides are found to be present in the gases.

These reactions afford an explanation of a circumstance which has for a long time been a difficulty in the minds of chemists who have studied the blast furnace. All observers agree that when the oxygen and carbon contained in the gases at various levels of the furnace are compared with the nitrogen, there is always more oxygen present than in ordinary air, and always more carbon than could be there were ordinary air burnt wholly to carbon oxide; thus the following Table illustrates the average composition by weight found by Bell in the case of an 80-foot furnace using calcined limestone:

Distance above Tuyere in feet.	0	6	12	25	37	50	60	76.5	Blast if wholly burnt.	
									To CO.	To CO_2.
Carbon dioxide	1.2	trace	0.8	1.2	1.6	1.2	3.5	7.9	....	29.2
Carbon oxide	37.6	37.1	35.9	34.9	34.8	34.8	33.2	33.0	34.4	....
Nitrogen	61.2	62.9	63.3	63.9	63.6	64.0	63.3	59.1	65.6	70.8
CARBON and OXYGEN in the GASES at DIFFERENT LEVELS, calculated per 100 of NITROGEN.										
Carbon	26.8	25.2	24.6	23.9	24.1	23.8	24.0	27.5	22.5	11.3
Oxygen	36.5	33.7	33.3	32.6	33.1	32.4	33.9	41.6	30.0	30.0

The presence of this excess of oxygen is readily accounted for when it is remembered that even at the lowest portions of the furnace some oxygen is still left in the ore, which is eliminated only at that point, necessarily in association with carbon, and that at this level the nitrogen of the blast is partially removed in the formation of cyanides. The anomaly, however, presents itself that the amount of oxygen appears to *diminish* from the tuyeres to a point some 10–12 feet above them, whereas it might be expected to increase, since the reduction of iron oxide is going on in the interval between the tuyeres and this point; inasmuch, however, as nitrogen is probably eliminated from the cyanide by its reaction on the residual oxide of iron throughout the whole of this interval, it results that *the nitrogen increases relatively to the carbon and oxygen in the gases;* or, what is the same thing, these diminish in reference to the nitrogen.

We are now in a position to trace out the general chemical changes undergone by the oxide of iron in passing through the furnace; for this purpose we may divide the furnace into three regions; in the uppermost tendencies [A] and [D] jointly are stronger than [B] and [C] jointly, and hence rapid reduction of ferric oxide takes place; in this region, too, tendency [C] is more powerful than [D] and [E] jointly, and hence carbon deposition takes place to a large extent. In this region, too, the limestone is for the most part calcined into quicklime, whilst if raw coal is the fuel employed, it is here coked; if carbonate of iron be used instead of oxide, it becomes converted into oxide in this region, the reducing and carbon-depositing reactions going on simultaneously with the formation of oxide.

In the middle region the iron-reducing tendencies are almost balanced by the iron-oxidizing ones, whilst the carbon-

depositing tendencies are equalled and perhaps slightly excelled by the carbon-oxidizing tendencies: here reduction takes place, but only languidly, the chief effect produced in passing through this region being an increase of temperature.

In the lowest region, the reduction of the residual iron oxide is completed chiefly through the agency of the cyanides formed in the vicinity of tuyere; the reduced iron melts, dissolving a certain amount of the finely-divided carbon in contact with it, together with small quantities of sulphur, silicon, and phosphorous reduced by subsidiary reactions. The earthy constituents of the ore and the lime of the limestone also fuse, forming "slag" as above described. In the act of cooling, this solution of amphorous carbon in molten pig iron undergoes a remarkable change, whereby the carbon is converted to a greater or less extent into the allotropic modification graphite, which is insoluble in molten iron, and so separates in crystals, thereby giving a crystalline structure to the pig, and forming "gray" iron of a quality varying with the nature of the foreign ingredients which retard the allotropic transformation (*specimens exhibited*): thus in white iron and in spiegeleisen the transformation does not take place to any appreciable extent before solidfication. This allotropic change is precisely similar to that undergone by a solution of yellow phosphorous in carbon disulphide by exposure to light; in each case the more stable allotrope formed (graphite and red phosphorous) possesses less "intrinsic chemical energy," *i.e.* gives out less heat on combustion, so that the allotropic change is attended with an evolution of heat. The accompanying specimens of recently-prepared phosphorous solution (perfectly clear), and a portion of the same solution exposed to sunlight for some days (full of flakes of red phosphorous), illustrate this change. (*Specimens exhibited.*)

This action of light on phosphorous is in several respects analagous to the changes produced in various attenuated vapors by passing a powerful beam of light through them, as ably described and illustrated in this room by your Professor of Physics on a former occasion.

Had time permitted, I should have wished to refer to the practical consequences of these researches of Mr. Bell. In order to effect the smelting of iron a certain definite amount of heat is required to perform the general work of the furnace; the various items in this amount are indicated by the following Table:

APPROPRIATION of HEAT in an 80-FOOT FURNACE, during the PRODUCTION of 20 CWT. of PIG IRON from CLEVELAND ORE.

Constant requirements of furnace :	Cwt. Heat-units.	
Reduction of Fe from Fe_2O_3	33,108	
Impregnation with carbon	1,440	
Reduction of P, S, and Si	4,174	
Fusion of pig iron	6,600	
Radiation from walls of furnace	3,658	
Cooling tuyures by water	1,818	
Conduction to earth and other sources of loss not determined	3,202	
		54,000
Variable sources of loss of heat :		
Fusion of slag	16,720	
Expulsion of CO_2 from limestone	5,054	
Decomposition of ditto	5,248	
Decomposition of H_2O in blast	2,720	
Evaporation of H_2O in coke	313	
		30,055
Carried out by escaping gases		8,860
Total		92,915
Brought in by hot blast		11,919
Heat produced by combustion of coke		80,996

To produce this heat with a minimum expenditure of fuel, it is necessary that the whole of the carbon used as fuel should be oxidized in the furnace to carbon dioxide; the relative strengths of the forces involved in the 9 reactions above described are, however, such that it is not possible to convert more than about 35 or 40 per cent. of the carbon burnt into carbon dioxide, the rest necessarily escaping as carbon oxide. Hence much less heat is generated in the furnace than would be if the fuel could be wholly burnt to carbon dioxide; that is, more fuel must be used to do the work of the furnace. It hence results that if the exigencies of commerce or of nature should require that metallic iron should be obtained from its ores with the consumption of a materially less amount of fuel than is now necessary for the working of a blast furnace of the best description, some wholly dissimilar form of apparatus will be requisite for the purpose. [C. R. A.W.]

PUMPING-ENGINES.—At the last meeting of the North Staffordshire Institute of Mining Engineers, Mr. Woodworth, of Longton, read apaper on recent improvements in pumping-engines for mines.

In the course of his reading he remarked that in designing steam machinery of all kinds, the great questions to be borne in mind were economy of fuel, of maintenance, and of construction. The importance of economy of fuel was manifest when they considered that the steam-engines in this country alone consumed nearly forty million tons of fuel per annum, so that a small percentage of saving, by whatever means obtained, represented a considerable addition to the national wealth. While the cost of coal in Cornwall had been a subject of vital importance ever since the steam-engine was introduced, it was not to be wondered at that the earliest steps were taken to secure as great an advantage as possible by the economical use of steam in draining the mines, although they found that the duty of the engines in that district had receded considerably for the last twenty years or so, as the rage for extreme limits of expansive working had been carried so far that the cost of maintenance and risk of accidents were so great as to more than counterbalance the benefits derived from an extreme range of expansive working. The Cornish engine in itself was a very costly machine in the first case, being only a simple-acting engine, and lifting a constant load compelled it to have a great weight of matter to put in motion quickly during the first portion of the stroke if worked expansively, so that sufficient energy could be stored up to enable it to complete its stroke after the steam was cut off at the point desired, and then the water was lifted steadily on the outward stroke by the action of gravity alone; while the differential pumping engine could be fixed either at the bottom of the pit, dispensing with the cumbrous rods entirely, or on the surface, as desired, and working double acting, was nothing like so costly, either in engines or buildings, for the same power, and such was the absolute safety of the action of the valve gear, that the load might be entirely thrown off when the engine was in full work, with the stop valve wide open with impunity. For the draining of dip workings the late Messrs. Garrett, Marshall, and Co. designed the direct-acting hydraulic engine and pump to be worked from the main column of pumps, or anywhere where sufficient water-pressure was available, and there was a wide field for its application in all districts where there was a head-pressure of water, which was often to be had at a nominal cost. The differential engine had been in operation for some years, and had been fixed in a number of collieries, the highest lift at present being at Clay Cross, where they were working against 1000 feet head of water; and some very large ones were being made for Germany, to pump against 900 feet head of water, with hydraulic engines to pump for a short distance below, to avoid all risk of the engines being flooded through any cause, as the hydraulic engines would continue working equally as well under water as above. Attention was called to the engine designed by Mr. H. Davey, of Leeds, and for which many advantages were claimed.

HYDRO-THERMIC MOTIVE POWER, &c.—A series of inventions, closely connected with each other, have been patented by Mr. F. TOMMASI, of Paris, embracing three applications of hydro-thermic motive power, the first being an improved motive power engine. This machine is composed of two or more cylinders, filled with oil or other liquid; it is set in motion by the alternate expansion and condensation of this liquid. To produce the expansion hot water or steam is made to circulate through small tubes plunging into the liquid, and to produce the condensation cold water or any other refrigerating mixture is made to pass through the same small tubes. The liquid expanding and condensing alternately drives the pistons in and out of their cylinders, thus producing a come and go motion, which may be transformed into a circular motion by ordinary means. If, as is preferable, hot water is used, the actual working of the machine returns to the boiler the hot water which has circulated through the small tubes, thereby giving a great saving. The distribution of the steam or hot water

and of the cold water is effected by means of ordinary side valves, set in motion by a cam, in lieu of an eccentric, in order to render the distribution almost instantaneous.

The improved hydro-thermic riveting machine, based upon the same principle, is set in motion by the alternate expansion and condensation of oil or any other liquid contained therein. To produce the expansion hot water or steam is made to circulate in small tubes plunging into the oil or other liquid; and to produce the condensation cold water or any other refrigerating mixture is made to circulate through the same small tubes. When the liquid is under expansion it lifts a vertical piston, which raises counterweights. The hot rivet is then placed between puncheons, one of which is stationary, and the other fixed to a horizontal piston, which, like the first-mentioned piston, also plunges into the liquid; this horizontal piston is clutched by a cam lever, but at this moment it is released (and driven by the pressure of the other piston, which is rapidly brought down by its counterweights), suddenly advances, and rivets the rivet. The cold current is then substituted for the warm one, the horizontal piston is brought back, to its place, and the operation recommenced.

The third patent relates to an improved hydro-thermic punching machine, which is set in motion by the alternate expansion and condensation of oil or other liquid contained in the machine. To produce the expansion hot water or steam is made to circulate within small tubes plunging into the oil or other liquid; and to produce the condensation cold water or other refrigerating mixture is made to circulate through the same small tubes. When the liquid is under expansion it drives down a piston furnished with a punch, and thus punches the plate of metal submitted to its action. The descent of the piston also effects automically (by means of a particular arrangement of side valves or cocks) the substitution of the cold circulation for the hot one, which brings the piston back to its place. The return of the piston to its place substitutes the hot circulation for the cold one, the work recommences, and so on.

EMERY.—The crude emery stone, which is a variety of corundum, has never been found in any considerable quantity for consumption, except in the countries bordering on the eastern part of the Mediterranean Sea, near Smyrna, on the Asiatic Continent, and on the contiguous island of Naxos, from which two sources all the world is supplied. Emery is very abundant in the island of Naxos, at Cape Emeri, which is the property of the Greek Government. Dr. Lawrence Smith, the American geologist, while residing in Smyrna, made a discovery of a deposit of emery. He made an examination of the locality in 1847, and having reported his discoveries to the Turkish Government, a commission of inquiry was instituted, and the business soon assumed a mercantile form. All that is used at present in the arts comes from Turkey, near ancient Smyrna, and from Naxos, which sources seem to be the same geological deposit reaching under the sea, from the Continent to the island, in the same manner as the basaltic formation of the Scotch Fingal's Cave and the Irish Giant's Causeway stretches under the Irish Channel. A few years since there was found in Hampden County, Mass., U.S.A., a species of hard iron ore, and, during the late civil war in America, large quantities of it were mined and crushed, and sold in the United States as real emery; but chemical analysis and experience in its use have shown consumers its different nature. The contractors who work the Turkish and Greek mines are obliged to mine, at each, from 2000 to 2500 tons per annum. The maximum annual product, and the total consumption of crude emery for all uses, does not exceed 5000 tons, and often falls below that quantity, of which the Wellington Mills, London, consume one-fourth of all that is yearly mined. The mining of the emery is of the simplest character; the natural decomposition of the rock in which it occurs facilitates its extraction. The rock decomposes into an earth, in which the emery is found embedded. The quantity procured under these circumstances is so great that it is rarely necessary to explore the rock. Its color varies from red-brown to dark brown. Its specific gravity is about 4.4, and it is so hard as to scratch quartz and many precious

stones. The earth in the neighborhood of the block is almost always of a red color, similar to red oxide of iron, and serves as an indication of its proximity to those who are in search of the mineral. Sometimes, before beginning to excavate, the spots are sounded by an iron rod, with a steel point, and when any resistance is met with, the rod is rubbed in contact with the resisting body, and the effect produced on the point enables a practiced eye to decide whether it has been done by emery or not. The blocks, which are of a convenient size, are transported in their natural state, but are frequently broken by large hammers. When they resist the action of the hammers, they are subjected to the action of fire for several hours, and on cooling they commonly yield to blows. The crude stone is shipped in blocks of various sizes, from 150 lb. in weight, down to pieces the size of an egg, but large stone is preferred, being more compact and hard. It sometimes happens that large masses are abandoned, owing to the impossibility of breaking them into fragments of a size convenient for transportation to the sea coast, camels and horses being the only means of transportation.—*Emery Grinder.*

REPORTS OF ENGINEERING SOCIETIES.

THE AMERICAN ASSOCIATION.—Last summer, at the Hartford Meeting of the American Association for the Advancement of Science, a new constitution was adopted, and under its provisions a permanent sub-section of "Chemistry, chemical physics, chemical technology, mineralogy, and metallurgy," was organized. Professor S. W. Johnson, of Yale College, was elected Chairman of the new sub-section for the ensuing year, and Mr. F. W. Clarke was deputed to make the necessary efforts to insure a full attendance of chemists and others interested in the application of chemistry. The meeting for this summer will be held at Detroit, commencing the 11th of August, and continuing about a week. It is very desirable that there should be a full attendance in the new sub-section in order to make it a success. Any one who is interested in chemistry, mineralogy, or any application of these sciences will be welcome.

Hitherto chemistry has been but little represented in the proceedings of the Association, and the time now seems to have arrived in which some good work can be done.

IRON AND STEEL NOTES.

BESSEMER AND SIEMENS-MARTIN STEEL.—A foreign cotemporary thus discusses the relative merits of the Bessemer and the Siemens-Martin process: There are at least two defects in the application of the Bessemer process, or perhaps it would be better to say, two obstacles to be encountered in the practical working of the method, that seem very difficult to overcome. One is the almost impossibility of using directly pig irons containing sulphur and phosphorus in any appreciable quantities, and the other the difficulty of controlling the quality of the product. These obstacles are too well known to need enlargement. Though the first is not so serious in America as in England, owing to the large deposits of ore in various localities suitable for the manufacture of Bessemer pig, nevertheless the cost of making pig suitable for this process is so much greater than the cost of ordinary pig as to be a large item in a ton of rails. The difficulty in controlling the amount of carbon is also well known, and is a serious item in the expense. In every cast made the carbon must be determined, sometimes by chemical analysis, and again by tests of a mechanical nature.

The Siemens-Martin method has the advantage of the Bessemer in these particulars—irons containing a much higher percentage of both phosphorus and sulphur can be used, it being estimated that about two-thirds of the sulphur and three-fourths of the phosphorus are eliminated in the process. The crop ends of bars, scraps, all descriptions of waste and old wrought iron, can also be utilized; in a word, grades of pig iron that could not be used in the Bessemer process, and much that would be waste, can be readily used. In the Siemens-Martin process the quality of the product is completely under control. Should the metal at the time of testing be too soft, more pig can be added; while, if it is too hard, simply waiting a few minutes will correct this, and materially soften the metal. The loss in the open hearth process is considerable less than in the converter—according to Gruner, about one-half.

The great advantage of the Bessemer process is in the larger amount of steel produced per day, and the cheaper cost of production. In some instances the amount has, with a pair of five-ton converters, exceeded 200 tons; while 10 tons would be a good day's work with an ordinary open hearth furnace. With the Pernot modification of the Siemens-Martin furnace, there is a prospect that this objection may be overcome. It is claimed that, with Pernot's furnace, 40 tons per day of Siemens-Martin steel can be produced, and we have the authority of an eye-witness for saying that the claim is well-founded. If this is true, with six of these furnaces a product fully equal to that of a pair of five-ton Bessemer converters could be obtained. The cost of the plant would not be more than half that of a Bessemer, the quality of the product could be controlled with ease, pig iron inferior to that used in Bessemer could be utilized, all scraps could be worked over, and the cost of steel equal in grade to Bessemer would not exceed the latter.—*Bulletin.*

RAILWAY NOTES.

A Siberian Railway.—Some hundreds of the principal merchants of Russia have forwarded an address to the Russian Minister of Public Works, asking that the construction of a railway to Siberia *via* Nijni-Novgorod may be accelerated. Surveys for the proposed line were made so long since as 1867 and 1868, but since those years scarcely anything has been done in the matter.

Underground Railway at Constantinople.—A telegram from Constantinople announces the opening of the Pera and Galata Underground Railway. The length of this line measured between the facades of the two termini is 635 metres. The station of Galata is situated between the Koumrou and Sevoud Streets; and that of Pera, which is not yet completed, in the Rue Nadir. The tunnel is ventilated by two shafts, one of which is 24 98 metres in depth, and the other 20.23. This railway is worked by a fixed engine, the carriages being hauled by a rope at the rate of 18 kilometres—11¼ miles—per hour; the trains are run at intervals of five minutes. The difference of level between the two stations is 60 metres, so that the average gradient is about 1 in 10. It is estimated that the number of passengers carried daily will be 30,000. The cost of construction of this line was upwards of 5 millions of francs—£200,000.

Improvements in Rolling Stock.—The artizans of the German Railway administration, in their sixth annual, report that locomotive boilers made of sheets of cast steel have not fulfilled the expectation entertained for them, although it is hoped that more favorable results will be obtained when improvements have been made in the manufacture of the steel plates. Copper bolts are recommended for the first row; steel ones are only to be employed when the feed-water and fuel are both good. Locomotive boilers have been made to resist a pressure of ten atmospheres. Screw link motion answers well for locomotives where the slide motion is not too heavy. In general the lever is to be preferred. Cast iron slide valves are good, and last longer, if the material possess the right hardness; brass ones are expensive and soon wear out; iron bronze gives satisfactory results; slide valves with partial lining do well, but cannot be employed if grooved. A number of companies have had bad luck with lined valves. For locomotive and tender axle boxes a majority of the railway companies recommend brass with white metal lining. Some had favorable results from the use of white metal alone; very few employ the red without lining it with an alloy, usually 87 parts copper and 13 tin, or 23 parts copper and 5 tin, also 82 copper and 18 tin. No definite results have been obtained from the use of phosphor bronze. The Heberlein brake has been generally successful; yet in many respects it may be improved. Iron blocks or shoes are gradually replacing wooden ones for brakes; wrought iron shoes have not been sufficiently tested, cast iron ones wear out quite rapidly, which makes them expensive. Those of cast steel or cast iron mixed with steel filings are recommended.

Punching Rails in Place by Steam.—A new machine for punching has been introduced into the railway world of America called Dudgeon's Hydraulic Punch, to which steam has recently been applied by Mr. N. Tilton, for punching rails in place, and as the application seems to have been successful, we reprint the report of this gentleman on the same:

The thickness of rail where punched is $\frac{5}{8}$ and $\frac{3}{4}$ inches, is the old pattern of chair or Erie rail, and is of such shape that at the top and bottom of the hole the thickness is $\frac{3}{4}$ of an inch, while at the centre it is but $\frac{5}{8}$, and is therefore much more difficult to punch than if rolled with two very nearly parallel faces. The portion of our iron which has been repaired at the ends is in most cases thicker by $\frac{1}{8}$, and sometimes $\frac{1}{4}$ inch; this, of course, makes it still more difficult to punch.

The size of the holes is 13-16 by 1 inch. When working one punch by hand we have only been able to punch from fifty to eighty holes in one day. By steam we have punched from 100 to 200 per day. The reason that more are punched in one day than another is, that we at times work one or two days without breaking a punch or die, and at other times have broken as many as four punches and one die in a single day. The causes of the breakage of so many are the irregular shapes of iron, the difficulty of getting the top and bottom of the punch to strike at the same time; if too high it crowds down, and if too low it crowds up. I mean by irregular-shaped iron that which has been repaired. It only requires ordinary care to be able to punch the holes accurately. No trouble has been experienced in making the plates fit properly. It is desirable that both punches be worked side by side, but impracticable, as one or the other is almost daily breaking punches, or having to stop to renew the leather packing in the ram or screw of the punch.

To work one punch by hand, it requires eight men; two to go ahead and draw the spikes, remove the chairs, and block up the rail one inch high; three men are required to work the punch, one to put on the plates and bolts, and two to tamp up the ties after the punch. I think the maker of these punches claims that two men are all that are necessary to work the punch, but we have found it necessary to use three. To work one of our steam punches, it requires twice the number of work. To work the punch but two are required. The cost of the fuel, &c., to run the steam punch does not exceed one dollar per day.

The breaking of the dies and punches, and the repacking of the rams and screws is about equal to that while working by hand, in proportion to the work done. I think we should break but few punches and dies, nor should we destroy the packing of rams and screws often, if we had iron to punch of the ordinary "fish" pattern, where the two sides are so nearly parallel, for the reason that there would be no tendency to crowd the punch down or

up. It is often the case, with our "Erie" iron, that the die goes down and the punch goes up, thereby forcing them "out of line," resulting in breaking one or the other—sometimes both—or the packing is destroyed in the screw or the ram.

I am satisfied that the steam punches are doing the work much more economically than it could be done by hand, and twice as fast. The cost of each will, of course, have to be considered, together with the quantity of work to be done. It has cost us about 600 dols. to apply steam to each punch.—*Iron.*

ENGINEERING STRUCTURES.

AN AERIAL BRIDGE.—A great engineering work, the only one of the kind in France, is about to be executed at Lyons. It is an iron bridge to connect the plateau of Fourviers with that of the Croix-Rousse, which are two heights, like that of Montmartre in Paris, at a distance of 300 metres from each other. *Galignani* says: This undertaking is estimated to cost 2,800,000f., of which a subvention of 600,000f. only is asked from the city. This aerial bridge will consist of three spans, the central one of 135 metres, and two others of 70 metres each, resting on open iron columns in a line with the houses on the quays. The platform of the bridge will be 65 metres above the road, and nearly 50 metres above the houses. Each of the two central columns will have inside a lift by which pedestrians will be raised in two minutes at a charge of ten centimes, to the top, whence they may reach the higher parts of the city, where they may have business.

AN IMPORTANT ENGINEERING WORK IN PORTUGAL.—From St. Michaels an official report has been issued with regard to the progress of the works for the construction of the artificial harbor of Ponta Delgada. It is mentioned that the breakwater forming this artificial harbor has attained an extent of 580 metres, the projected length being 860 metres at low-water mark. In 1873 no progress was made as regards length, the whole of the stone thrown into the sea—amounting to 67,290 English tons—having been employed in completing the section at the far end, as a considerable portion had been washed away during the gales of the previous winter. The expenditure during the year was £19,325, making a total of £317,722 since the commencement of the works. With regard to the extent of the works, it is calculated that as much as 2,341,104 tons of stone will be required to complete the breakwater, and that of this amount nearly 2,000,000 tons have already been employed. The portion so far constructed, we learn, does not yet present the form definitely adopted—that of the breakwater at Holyhead but has an appearance of solidity which is a guarantee of its resistance against the violence of the sea. To effect the completion of the work it is believed that ten years will be required, and that the annual grant of about £18,000 will not be exceeded. The part of the artificial harbor already sheltered has an area of about 25,000 square metres, with a depth varying from 10 ft. to 30 ft. below low-water mark. Vessels drawing 20 ft. can enter this part of the harbor. The part of the artificial harbor corresponding to the portion of the breakwater still to be completed will present an area of more than 90,000 square metres, with a depth varying from 10 ft. to 60 ft., and admitting about 100 vessels of all sizes. The construction of a new quay has also been commenced, alongside which vessels drawing 18 ft. will be able to discharge. It is stated that the length of the quay will be 50 metres. The engineer who has the direction of the works of the artificial harbor of Ponta Delgada is Senor Alvaro Kopke de Barbosa Ayalla.—*Engineering.*

EFFECTS OF HEAT AND COLD ON THE ST. LOUIS BRIDGE.—We have here in St. Louis a bridge with arches of 500 feet; and, to any one who has the proper means of observation, the changes in the elevation of the crown of the arches are very perceptible. In the construction of the work, calculations and allowances were made for the extremes of temperature, through a range of 140°, from the greatest cold in winter to the warmest day of summer, and the calculated difference in the elevation of the center arch of the upper chord above the City Directrix at these two times was about eighteen inches.

The bridge has now long been finished. During the year, the height of the center piers of the top chords of the arches above the City Directrix has been noted almost daily at temperatures which have ranged from 92° to 15° Fah., the elevations being taken with a level from the abutments of the bridge.

(The "height" is that of the center pier of the top chord above the City Directrix):

Date.	Temp. 3 P. M.	Height in feet.
May 6th, 1874	69° F.	63,548
June 29th, 1874	77° F.	63,688
July 20th, 1874	91° F.	63,757
January 4th, 1875	10° F.	63,241
January 9th, 1875	15° F.	63,065

Between the figures for July 20th last and those for January 9th, which two days are respectively the warmest and coldest of the year, there is a difference in temperature of 107° Fahrenheit, and of 0.692 feet, or nearly 8 5-16 inches.

This is an effect of temperature much less than calculated, due partly to the fact of the iron work being painted white, which lessens the absorption of heat in hot weather, and increases the radiation in cold weather, and also the protection afforded by the roof of the bridge. This latter is strikingly exemplified in the fact that the river, while frozen above and below the bridge, has yet been open under it.—*Railway World.*

IRON BRIDGE CYLINDERS.—The following hints on this subject are taken from Mr. John Newman's useful pamphlet on "Iron Cylinder Bridge Piers," recently reviewed in these columns: As the strength of cast iron

depends upon its rigidity, it is necessary to stiffen the cylinder rings by lugs or brackets, and vertical and horizontal flanges, which also form the joint flanges. The joints should be made slightly stronger than the solid parts of the work, as they are subject to special defects, such as unequal bearing, &c. The vertical and horizontal flanges of the cylinder should be well and firmly bolted together, as the lateral strength of the cylinder is thereby secured. It may be as well in cylinders of small diameter to lessen the length of each ring and make them in one piece, thus obviating the necessity of any *vertical* joint flanges, and with the increased facilities and improved machinery now in use, many ironmasters will do this without any extra charge. In tropical climates, where the atmosphere affects the metal to a greater extent than in Europe, ample allowance in the thickness of the cylinder should be made. There is greater liability to imperfections in the castings if the rings forming the cylinder are cast horizontally instead of vertically. In increasing the thickness of the rings of the cylinder, the same unit of strength per square inch for the increased area does not hold, for beyond a certain thickness the value per square inch decreases very considerably. The author would never use a less thickness of cast iron in the rings of the cylinder than 1 inch, or a greater thickness than 2½ inches, and this latter only as an exceptional case; and for the bottom ring, which, to facilitate the sinking, is generally brought to a taper. Castings are generally made of greater thickness in practice than the requirements of theory show as necessary. Cast iron is more liable to be broken by collision with floating substances than wrought iron. It is usual when a bolt passes through a piece of cast iron to increase the thickness of the metal at that point to a little beyond where the head or the nut of the bolt extends. A bad joint will often not be discovered on testing a structure, but only after it has been subject to continuous strain and vibration; thus the importance of good and sound joints is evident. It is advisable to make the bottom ring of the cylinder thicker than the other rings, on account of the greater cross strain, &c., it has to bear. Much of the strength of a casting depends on the design. There should be as few abrupt bends, sharp angles, and sudden variations of thickness as possible, in order to obtain equal and uniform cooling, and accord in the order and direction of crystallization, as it has been found from experience that wherever the order of crystalization is disturbed there will be found weakness. Increased thickness should not be considered as an equivalent to inferior iron, for in no material can it be said with greater truth that it is absolutely necessary to have quality as well as quantity.—*Iron.*

THE LONDON WATER SUPPLY.—In reply to Lord Cadogan, who in the House of Lords the other evening asked what the Government intended with regard to the better and purer supply of water to the metropolis, the Duke of Richmond referred to a Bill which the Chelsea Company had now before Parliament for enabling them to draw from a source higher up the Thames than they have at present. The Chelsea Company was specially complained of by Lord Cadogan, and a friendly journal which includes in its title the advocacy of sanitary improvement, admits that this company is "unhappily every now and then obliged to distribute water somewhat turbid, which, when it gets into a cistern, deposits something like mud." Turbid water, when allowed to settle, does, it must be admitted, usually deposit something that cannot be easily discriminated from mud. From Major Bolton's report for January to the Local Government Board, we learn the composition of this sediment, resembling mud, which the company referred to dispenses to its customers. The greater part of it consists of the chalk and clay carried down by floods, and to this must be added the solid matters of the "filthy outflow of the rivers Mole and Rye," below which the intake of the company is situated. No wonder, then, that a deposit "thick and slab" should appear in the cistern. Major Bolton's general report is pretty favorable, and he shows that great difficulty has been experienced by the companies in their filtering operations during the prevalence of the recent extraordinary heavy floods, which tended to choke the filters by a deposit of chalk, mud, and clay upon the surface of the sand, thereby rendering the utmost vigilance and exertion on the part of the companies necessary to enable them to properly filter their supply. With the praiseworthy intention of allaying the public alarm and anxiety, he draws attention to the following extracts from the report of the royal commission on the quality of the water from the Thames basin:—"The evidence before us leads to the conclusion that the Thames water has many good qualities which render it peculiarly suitable for the supply of the metropolis, and which give it in some respects a superiority over the soft waters usually obtained from high gathering grounds. When properly filtered, it is clear, bright, colorless, agreeable, and palatable, and the amount and nature of its saline constituents are considered by many to contribute to its general acceptability for drinking. It is well aerated, has good keeping qualities, and is unusually safe as regards action on lead and iron. The evidence we have collected on the subject of the organic impurities of this water presents great diversities of opinion, but there is one result which we think is clearly deducible from the facts before us, namely, that in the present state of chemical science (1869) analysis fails to discover in properly filtered Thames water anything positively deleterious to health. Whatever may be the difference of opinion with respect to the time required for removal of all the objectionable organic matter, all the chemists agree that in Thames water taken from the present source and properly filtered, all such matter has disappeared, and that the resulting compounds, such as nitrates, &c., remaining therein, are innocuous and harmless."

ORDNANCE AND NAVAL.

GERMAN ARTILLERY.—It is stated by Prussian artillerists that, notwithstanding certain adverse comments made on their new heavy field pieces in the reports of the Vienna International Exhibition, it has been privately resolved by the Austrian War Office that the whole of its artillery shall be converted as speedily as possible to a model borrowed directly from the Prussian.

A BRAZILIAN ARSENAL.—The length of the workshop quays at the Brazilian arsenal, at Ponta d'Ares, is 300 metres; and the breadth of the quays is from five metres to six metres. The great boiler shop has 14 machines for pressing, punching, cutting and bending bars and plates of iron; all these machines are driven by a portable steam engine of 25 horse power. The arsenal turned out last year several bridges of wide span for railways, and a number of boilers, both tubular and common. The machine shop has 48 machine tools of various types.

BOOK NOTICES.

DIAGRAMMAGRAPHIC. By S. PICHAULT. Price, $2.40. Paris: J. Dejey & Co. For sale by D. Van Nostrand.

This is a treatise on theoretical and practical use of an "Indicator," whose construction is fully described by text and plates.

LES CROISEURS; LA GUERRE DE COURSE. Par P. DISLERE. Paris: Gauthier—Villars. Price, $2.40. For sale by D. Van Nostrand.

This is a sketchy account of modern ships of war, particularly of the English, French and American navies. There are a few cuts and many statistical tables.

FOSSES D'AISANCES. Paris: J. BAUDRY. $8.00. For sale by D. Van Nostrand.

This is an elaborate treatise on the theory and use of the water-closet and its congeners.

The work ought to be of great value to the practical plumber, the sanitary inspector, and the hospital surgeon.

We had no idea of the extent of the subject until we turned over the pages of this work. There are 550 pages of text, and 232 excellent wood-cuts.

ANNUAL REPORT OF THE STATE ENGINEER AND SURVEYOR OF THE STATE OF NEW YORK ON THE RAILROADS OF THE STATE. Albany: Weed, Parsons & Co. Price, $2.00. For sale by D. Van Nostrand.

This bulky volume of 1,037 pages presents in tabulated form all the statistics usually included in such reports; it includes also the "General Railroad Act," the laws amending the same, and other general laws relating to the railroads of the State.

NARROW GAUGE RAILWAYS IN AMERICA. By HOWARD FLEMMING. Price, 50 cts. For sale by D. Van Nostrand.

This is a compilation of statistics which have been much demanded for the last two or three years.

In addition to the engineering facts relating to the narrow railways, a complete directory of all such roads in this country is appended.

WOODEN AND BRICK BUILDINGS WITH DETAILS. A. J. BICKNELL. New York. 2 vols. Price, $18.00. For sale by D. Van Nostrand.

This is a collection of designs by many American architects.

The plates are large quarto size, and number 160.

The small amount of text is probably sufficient where detailed plans are so fully given.

Such examples by successful architects are invaluable to young aspirants to architectural fame.

ASTRONOMY. By J. RAMBOSSON. London: Chapman & Hall. Price $6.00 For sale by D. Van Nostrand.

This is a popular treatise presenting some acceptable differences from the average popular texts-books.

Historical sketches of early astronomers and their labors; the history of the earth's measurement; accounts of the great comets and descriptions of meteors and meteorites are rendered in a pleasant and readable form. The illustrations are highly colored but poor.

WOOD AND ITS USES. By P. B. EASSIE. New York: D. Van Nostrand. Price $1.50.

The text of this neat little treatise treats of the following subjects in order: Timber and Deals—Joists, Flooring and Girders—Roofs and Roofing Materials—Joiner's Work—Contractor's Plant—Green-Houses and Vineries—Useful Temporary Structures — Strains on Roofs and Bridges—Practical Memoranda and Tables.

Cuts to the number of 230 illustrate the text. That the work is eminently practical may be correctly inferred from the list of topics.

CONTINUOUS REVOLVING DRAWBRIDGES. By CLEMENS HERSEHEL. Boston: Little, Brown & Co. Price $1.50. For sale by D. Van Nostrand.

This was originally prepared for the American Society of Civil Engineers, and is in their published transactions. It is now put in an exceedingly neat form, and is entitled to place among standard works of engineering literature.

It will prove a valuable aid to students; the method of computation is arithmetical, and is extended to the important case of continuous girders.

ELEMENTS OF DESCRIPTIVE GEOMETRY. In Three Parts. Part I—Surfaces of Revolution; Part II—Surfaces of Transposition; Part III—Special Subjects. By Prof. S. EDWARD WARREN. New York: John Wiley & Son.

Nothing could be more thorough than the method of treatment of Prof. Warren in any department of Graphics. He is doubtless the most experienced instructor of these subjects in this country, and judging by the fruits of his labor among the young members of the

engineering profession he has been the most widely successful. He is the author of several works, but the one by which his skill as an instructor may be most accurately estimated is the complete work on Descriptive Geometry, divided into separate volumes as indicated above. The first part includes all of the ordinary college course in this department of science, while the remaining portions are designed to satisfy the wants of the most advanced technical schools. The former large work in one volume is out of print; and in re-writing the work a new arrangment of subjects was decided upon; this resulted in the above division.

RAPID TRANSIT AND TERMINAL FREIGHT FACILITIES. By a Committee of the American Society of Civil Engineers. Published by the Society. Price 75 cts. For sale by D. Van Nostrand.

A Committee of five members of the Society was appointed in September last "to investigate the necessary conditions of success, and to recommend plans for—1st, the best means of rapid transit for passengers; and 2d, the best and cheapest methods of delivering, storing and distributing goods and freight in and about the City of New York.

The two reports were rendered on March 3d and March 17th respectively, and are published together.

Considering the circumstances under which this report was framed, the professional standing of the several members of the Committee, and the influences which urged them to a careful consideration of the subject, we can safely say, that from no other source could such a document issue with so strong claims to our respectful attention.

ELEMENTS OF MACHINE CONSTRUCTION AND DRAWING. Elementary Plane Problems; Elementary Science Perspective; Linear Perspective. Prof. S. EDWARD WARREN. New York: John Wiley & Son.

The first of the above list is a good work for the young draughtsman, after he has mastered Geometry and Geometrical Problems. It presents in logical form the Principles of Gearing; of Screw Propellers, Valve Motions, Governors, &c., &c.

The plates are numerous and well designed.

For beginners in Graphics, the second of the above list is specially designed. It deals with the problems on the point, straight line and the circle, and furnishes excellent suggestions to teachers of Elementary Geometry in the way of applications during the student's early progress.

Elementary Linear Perspective is rudimentary. It is a small work of only 116 pages, and is illustrated with 66 cuts. It contains as much perspective as landscape artists attempt to acquire.

Linear Perspective presents the subject fully. It is a volume of 200 pages of text and 17 folding plates.

The following index of chapters will exhibit the scope of this excellent treatise:

General Principles—General Tables—Fundamental Problems—Perspectives of Forms only—Special Principles and Operations—Elementary Perspectives of Shadows—Problems of Forms and their Shadows—Perspectives of Reflections—Perspectives of Shadows by Candle Light—Distorted Perspections; Singular and Amorphous.

KNIGHT'S AMERICAN MECHANICAL DICTIONARY. A Descriptive Word-Book of Tools, Instruments, Machines, Chemical and Mechanical Processes and Engineering Works. By EDWARD H. KNIGHT, Civil and Mechanical Engineer. New York: J. B. Ford & Co.

This is an entirely new work, both in conception and construction, being at once a Cyclopedia of information on generic subjects, and, more especially, a Word-Book or Dictionary, with descriptive definitions of machines, tools, instruments, processes, &c., in their alphabetical order, forming a really complete reference-book of information concerning the mechanical appliances of science and the industrial and fine arts.

Mr. Knight, the author of this work, besides being a practical Civil and Mechanical Engineer of high attainments, has for many years been in that best mechanical school of the world, the U. S. Patent Office, where the most inventive and ingenious people of the earth bring in their new ideas. For years he has been employed to classify and systematize for examination the 20,000 inventions per annum which come pouring into that vast depot; and as the Editor of the Patent Office Reports to Congress, he has acquired a singular aptness, clearness, and terseness in describing the application of mechanical principles.

The technical illustrations, nearly 6,000 in number, are never introduced for mere ornament, but always to exemplify the text; and, besides being profuse in quantity, are clear, intelligible, and artistic.

THE IMPROVEMENT OF NAVIGATION OF THE ST. LAWRENCE RIVER.

The Chief Engineer's (of the Dominion of Canada) report on the St. Lawrence navigation improvements, including the canal enlargement, is out. There is not much in it that is new. The present canals are found to be too small to accommodate the growing trade of the west; they were designed with locks $200' \times 45'$ and 9′ water on the mitre sill, although there has been times when there was only 7′. The proposed canals are to have locks $270' \times 45'$ and 12′ water on the mitre sill at low water, and also have the other dimensions in proportion.

It is also proposed to have a chain-tug service in the rapids. This is not anything new, as it has been employed on the Seine below Paris, also on the Rhine, Elbe, Danube, and other rivers and canals in Europe, as well as at Hochilaga, below Montreal.

The chain is made fast to a pier above the rapid and to another below, and the tug works backwards and forwards on this chain.

There are some works in connection with those improvements that will be very difficult in execution, such as sinking piers in the rapids, &c.

It may be noted here, that a vessel that can

run 12 miles an hour cannot ascend a rapid running 7 or 8; and a man can tow a canoe in a rapid that 6 men could not paddle against the same current.

If some person could give some reliable information about this chain-tug towing, and also about the resistance of water to passing vessels, especially in strong currents, they would confer a benefit on the profession, as I think this is but little understood.

Those St. Lawrence navigation improvements are estimated to cost about $12,000,000, but if the chain-tug towing is adopted in the rapids it will reduce the cost to about $10,000,000. It is intended to complete the works by May, 1879. FRANK C. TREBLIZ.

ELEMENTS OF PRACTICAL CONSTRUCTION, FOR THE USE OF STUDENTS IN ENGINEERING AND ARCHITECTURE. Part I. Structures in Direct Tension and Compression. With Atlas of plates and woodcuts. By SAMUEL DOWNING, LL.D., Professor of Civil Engineering in the Untversity of Dublin. London: Longmans, Green, & Co. Price $7.00. For sale by D. Van Nostrand.

The utility of Prof. Downing's work on "Practical Hydraulics" has been so long recognized by engineering students, that it will be generally gratifying to them to learn he has now completed another work on the same general plan, embracinng the "Elements of Practical Construction;" so far as regards the resistance of materials to direct compression and tension, the subjects of elasticity, indirect compression and tension, transverse resistance and torsion; &c., being reserved for another volume. In treating of each material, a proposition is first given stating its average ultimate resistance; this is followed by experimental proofs, and then are given illustrations, of the materials so strained, taken from completed and successful structures of eminent engineers.

In the first chapter, which treats of the direct resistance to tensile forces, he explains the necessary conditions in good experiments, and points out the importance of the form of the specimen and construction of the apparatus employed. The ultimate resistance of cast-iron to a direct tensile force is about 7 tons per square inch, and is proportional to the area of transverse section in action. The ultimate resistance of wrought-iron to a tensile force is about 20 tons per square inch for boiler plates, and about 25 tons per square inch for the highest quality of rods and bars. Drawn wire under 1-10th in. diameter about 36 tons per square inch. It is mentioned with reference to Mr. Edwin Clarke's table of experiments, made at the Britannia Bridge, that it shows a very great constancy in the ultimate resistance. The ultimate extension, on the contrary, is extremely irregular; indeed, some of the brittle crystalline iron, selected as bad, and which fractured suddenly without much increase of length, actually supported a greater weight than the more fibrous and ductile iron. The professor explains that in appyling to the actual practice of construction the knowledge of the ultimate resisting powers of any material as obtained by experiment, the engineer must in all his designs keep in view the great objects of permanency, stability, and safety; and, therefore, assign to every part such dimensions and form that it shall be acting far within its ultimate power. But the question at once arises, How far within!—what fraction of the ultimate must be the actual resisting force called forth! For this no absolute rules can be set down; a careful judgment and sagacious use of existing precedents must alone guide us here; a knowledge not only of existing successful works—which from being, as may often occur, stronger than strong enough have, perhaps, purchased the stability at the expense of economy, and are consequently so far not to be followed; but also from the records of past failures, which are in truth but unintended, and expensive experiments.

In subsequent chapters the resistance of timber, direct resistance, to compressing forces, cast-iron and its practical application in compression, wrought-iron and practical application, direct resistance of timber and practical applications, and stone and brick. The direct resistance of stone to a compressive force varies from about 11 tons to $\frac{1}{2}$ ton per square inch, according to the formation from which it has been taken. He remarks that Portland cement, after a rather unpromising commencement, has at length obtained a very high degree of favor with engineers and architects, both on the Continent and in Great Britain, especially in works exposed to water. Compared with Roman cement it has the advantages, first, of being adapted for use both as an hydraulic mortar when mixed with sand in any proportion desired, and secondly, for concrete; also either in foundations, or as backing to front work, and even as grout. It is also claimed for it that it sets harder than the rival cements now nearly supplanted by it, but it has not the property of quick setting as compared with the natural cements, pozzolano, tarras, &c., or the artificial manufactures called Roman, Orchard, &c., cement. There are two appendices, the first treating of the best form of wrought-iron links or bars when resisting tensile strain, and the second containing an extension of Eaton Hodgkinson's tables for the diameters of columns.

It is unnecessary to state with regard to a work of Prof. Downing's that the utmost care has evidently been bestowed upon every portion of the volume, and that the language will make the several matters treated of clear even to the least attentive student, especially as the explanations are rendered still more easy of comprehension by the constant references made to the handsome atlas of plates which accompanies the volume.—*Mining Journal.*

OUTLINES OF PROXIMATE ORGANIC ANALYSIS FOR THE IDENTIFICATION, SEPARATION, AND QUANTITATIVE DETERMINATION OF THE MORE COMMONLY OCCURRING ORGANIC COMPOUNDS. By ALBERT B. PRESCOTT, Professor of Organic and Applied Chemistry in the University of Michigan. New York: Van Nostrand, Murray and Warren streets. Price $1.75.

Since the first appearance, now more than 30 years ago, of Dr. Will's "Outlines of the

Course of Qualitative Analysis followed in the Giessen Laboratory," it has become so customary for students of inorganic analysis to be taught from the moment they enter the laboratory to adopt a defined and scientific method of procedure, usually explained in concise language in a reliable text-book with which they are provided, that the younger chemists can scarcely appreciate the obstacles which the student of half a century since had to encounter in acquiring the knowledge requisite to give him even a decent position in his profession; yet it has been left for Prof. Albert Prescott, of the University of Michigan, to perform to-day a corresponding service for the students of organic analysis, and in doing so he has furnished an outline which, if not perfect, will assuredly form the basis upon which future systematic methods of organic analysis will be built. Well knowing that in so large a field as he has undertaken to cover, the labors of a single investigator would be of comparatively little utility for ascertaining the almost innumerable details which have to be recorded and discussed in treating of the similarities and differences of behavior of the several compounds, Prof. Prescott has wisely availed himself of the researches of all the best authorities, American and European, upon the several classes of substances dealt with, so that full reliance may be placed upon the information which he furnishes.

That organic compounds can be brought into a few and clearly defined groups as readily as inorganic matters or simple elements is not to be pretended; yet classification is no less important, and with the aid of Prof. Prescott's book it will be much facilitated. To give an idea of the manner in which the book is arranged, the first solid non-volatile acids may be taken as a sample. Tartaric acid $H^2C^4H^4O^6$, is described as being characterized by the form of its crystals and its rotation of polarized light (*a*), by its odor when heated, and its color when treated with sulphuric acid (*b*), and so on. It is then explained how it is separated (as free acid) from salts, &c., insoluble in alcohol, from alcoholic solutions, from citric acid, and so on; and it is then stated how it is determined. The several characteristics, modes of separation, and of determination are first given collectively and briefly, and afterwards separately and more in detail, so that the reference is greatly facilitated, the bracketed letters—(*a*), (*b*), &c., being references to subsequent portions of the same numerical paragraph containing the details. Thus turning to the twelfth division of the paragraph (*f*) it is found that free tartaric acid, unmixed with other acids may be determined volumetrically by adding a normal solution of soda to the neutral tint of litmus. Weighing 7.500 grammes, the required numbers of cubic centimetres of normal solution equals the number per cent. of acid. It is then explained how in the absence of acids forming lead salts it may be precipated, &c., and weighed as normal lead tartrates; when $PbC^4H^4O^6 : H^2C^4H^4O^6 :: 1 : 0.422535$. Similar directions are given for cases where it is expedient to weigh it as calcium carbonate, and for others where it must be determined as potassium bitartrate. These instructions occupy nearly four pages, but from the lucid manner in which the information is given every fact recorded can be referred to at a glance. The succeeding paragraph naturally treats of racemic acid, the isomer of tartaric, and it is explained that racemic is *distinguished* from tartaric as follows:—By forming triclinic crystals, $H^2C^4H^4O^6$, H^2O, soluble in five parts cold water, or 48 parts of alcohol of sp. gr. .809: slightly efflorescent on the surface losing the water of crystalization at 100°. By its solution (uncombined) being able to form after a short time a slight precipitate in solution of calcic sulphate, and a precipitate in solution of calcic chloride; the precipitate of calcic racemate being, after solution in hydrochloric acid, precipitated again by ammonia, that is not soluble in chloride of ammonium solution, by being inactive towards polarized light. The "Outlines" appear to include about 600 substances, most of which are treated with equal completeness.

For the reasons already given Prof. Prescott's volume is necessarily a compilation; but since it is a compilation involving a previously unattempted classification which, moreover, has been made with the utmost judgment, it has probably a greater claim to originality than many other books. After working with his class for several years without other aid than a manuscript digest of directions and references he is convinced, and there are very few who will disagree with him, that a compilation in this subject was desirable—not alone for students in special applications of chemistry, but for the convenience of every analyst. Froximate organic analysis, he remarks, is not altogether impracticable, and organic chemistry is not solely a science of synthetical operations even at present. It is true, as the chief analytical chemists have repeatedly pointed out, that in the rapid accumulation of organic compounds the means of their identification and separation have been left in comparative neglect. It is true also that the field is limitless, but this is not a reason for doing nothing in it. As a result of his labor, Prof. Prescott has produced a work which is well worthy of recognition as a text book both in England and America, and upon the utility and completeness of which he may well be congratulated.

MISCELLANEOUS.

DREDGING FOR AMBER.—According to an official report from Memel, Germany, an establishment has been organized for gaining amber by dredging for it in the Kurische Haff, near the village of Schwarzort, situated about twelve miles south of Memel. It has been known for many years that amber existed in the soil of the Kurische Haff, from the fact that the dredger employed by the Government for the purpose of clearing away the shallow spots near Schwarzort, which impeded navigation, brought up pieces of amber which were duly appropriated by the laborers, and at the time no particular attention was paid to the matter.